THE COORDINATING COMMITTEE ON GREAT LAKES
BASIC HYDRAULIC AND HYDROLOGIC DATA

HYDROMETEOROLOGY AND MODELING
SUBCOMMITTEE

HYDROMETEOROLOGICAL DATA COLLECTION DESIGN AND ANALYSIS FOR THE LAKE ONTARIO DRAINAGE BASIN

FINAL REPORT - PHASE I

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Preface

In February 1989, the Hydrometeorology and Modeling Subcommittee of the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data agreed to undertake an analysis of the existing hydrometeorological data collection network over the Lake Ontario drainage basin.

A coordinated Statement of Work was generated between participants in October 1989. In March 1990, the U.S. National Weather Service, sponsored by the U.S. Army Corps of Engineers, requested proposals to conduct this research. In June 1990, the U.S. National Weather Service awarded a contract to the Hydex Corporation, of Vienna, VA, under Contract 50-WCNW-0-06043 to "Provide Research and Development for Hydrometeorological Data Collection Design and Analysis for the Lake Ontario Drainage Basin."

The accepted proposal called for a three-phase, three-year investigation to evaluate the adequacy of the existing rainfall/snow collection networks maintained around the basin, the relationships of these ground-based observations to airborne snow and soil moisture collection networks, and the use of data collected from these networks in water supply / water level simulation and forecasting models developed for the lake and its drainage basin.

In February 1991, the Hydrometeorology and Modeling Subcommittee agreed to publish the reports of Hydex Corporation, under its authority. This report is the final report for Phase I of the study. Additional reports are expected to be generated for each of Phase II and Phase III, with a composite volume due upon completion of all study activities. Information on the activities to be conducted under Phase II and III can be provided by the Great Lakes Hydraulics and Hydrology Branch, U.S. Army Corps of Engineers, Detroit District.

Notice

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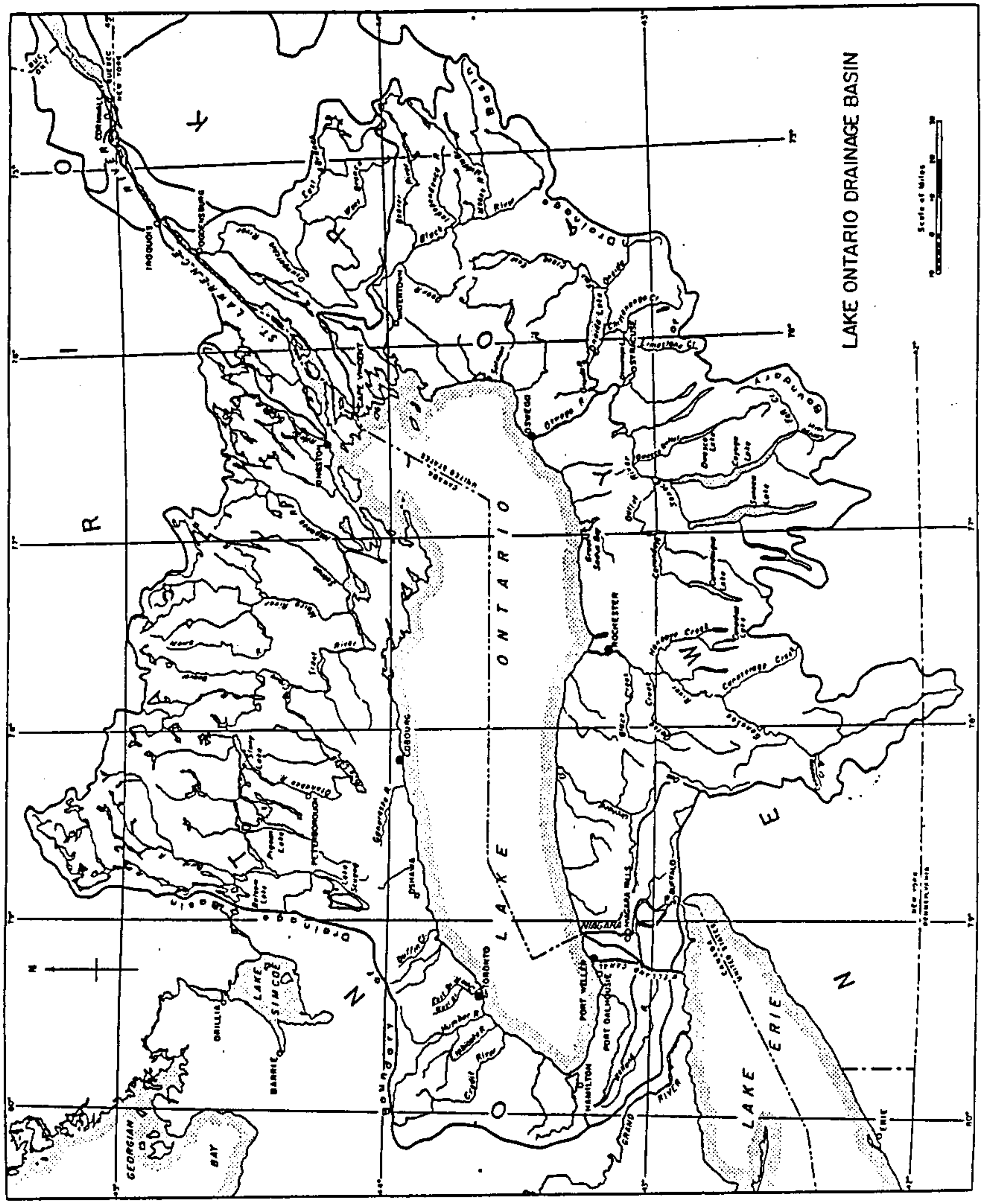
LAKE ONTARIO DRAINAGE BASIN
LAKE ONTARIO
LAKE ERIE
LAKE SIMCOE
GEORGIAN BAY
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NEW YORK
TORONTO
HAMILTON
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GRAND RIVER
ST. LAWRENCE RIVER
Scale of Miles

Hydrometeorological Data Collection Design and Analysis for the Lake Ontario Drainage Basin

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This work has been accomplished by the Hydex Corporation, Vienna, Virginia, under contract, 50-WCNW-0-06043, with the National Weather Service (NWS), National Oceanic and Atmospheric Administration (NOAA), Department of Commerce. The work has been sponsored by the U. S. Army Corps of Engineers (COE).

DEVELOPMENT OF DATA BASE

The primary effort during Phase I has been the development of the historical hydrometeorological data base and the preparation of the attached reports listing the locations and periods when snow cover measurements have been observed. The data base contains records for stations in those areas in Canada and the United States that drain directly into Lake Ontario. The time period for the study, determined through coordination with the NWS and the COE officials, is the 30-year period, 1961 to 1990 (where available, records are included in the data base starting in January 1955).

Information on records included in the data base for the US and Canadian drainage areas are presented in **Attachment A** (US) and **Attachment B** (Canada). The data base includes some, but not all, of the following records:

- Climate Stations
  - Daily (and Monthly) Precipitation
  - Temperature (mean daily and/or mean monthly)
  - Snow on Ground (daily)
  - Snowfall (daily)
- Hourly Precipitation Stations (Monthly totals only)
- Synoptic Stations
  - Daily (and Monthly) Precipitation
  - Temperature (mean daily and/or mean monthly)
  - Snow on Ground (daily)
  - Snowfall (daily)
  - Wind Movement (mean daily and/or mean monthly)
- Snow Surveys
  - Ground
  - Remotely sensed (airborne gamma)

As may be seen from the information in Attachments A and B, the data bases for the US and Canada are large and fairly comprehensive.

Most of the hydrometeorological records for the study area were not readily available and not in formats convenient for performing the planned analyses.

However, most records required for the initial and final quality evaluation of the records resides on the Hydex computer system.

Many agencies in Canada and the United States have been very cooperative in furnishing records. In Canada, these include the Canadian Atmospheric Environment Service (AES), Toronto, Ontario, the Ministry of Natural Resources, Toronto, Ontario, and Environment Canada, Parks Service, Peterborough, Ontario. In the United States, the Great Lake Environmental Research Laboratory (GLERL), the US Army Corps of Engineers (COE), the Northeast Climate Center of Cornell University, the NOAA Library (Rockville, Maryland), and the Office of Hydrology, National Weather Service (NWS). Information on the Lake Ontario drainage basins have been furnished on maps by the COE.

PROCESSING OF DATA

Monthly values of the hydrometeorological records (precipitation. temperature, snow on ground, snowfall and wind movement) are in tabular files with yearly values computed for annual, October-April and May-September periods and 30-year averages for stations that have complete records for the base period. These yearly totals, and 30-year averages for the same seasonal periods, are required to evaluate the quality of the records. Records of ground and airborne snow surveys for the US and Canada have been collected, processed and placed in tables.

A sample set of records has been evaluated for consistency and accuracy during Phase 1.

Problems with Respect to Data Base

One problem that is difficult to solve is obtaining adequate information on the history of stations sites (precipitation gages and ground snow surveys), such as information on current measurement sites, previous measurement locations, and on changes in equipment or observing techniques. This information is required for evaluation, and where indicated, for adjustment of records.

For the US precipitation stations, a complete set of available station history forms (Report on Substation and Cooperative Station) have been reproduced from NWS records and are on hand at Hydex. During the last few years the NWS has discontinued having the Substation Network Specialists prepare diagrams of the area surrounding a precipitation gage on their *Report on Substations*. Current instructions are to only provide limited digital information as to distances to obstructions, height of obstructions and angle from the orifice of a precipitation gage to top of the obstructions. Without these diagrams to provide information on all objects and terrain features in the area of a site that relate to exposure of a precipitation gage, the value of the precipitation records for hydrological modeling and other critical purposes is greatly reduced. Consideration should be given to alleviating this problem by having the NWS substation network specialists prepare diagrams for climate and synoptic precipitation stations in northern areas that receive considerable snowfall along with the digital information they are presently providing.

Station history information as to dates stations were moved are available for Canadian precipitation stations, but detailed descriptions of most stations are not available. Information on the exposure of Canadian synoptic stations equipped with Nipher gages has been furnished by the AES.

Station history information for US snow survey measurement sites such as moves, description of sites, and description of observing techniques or number of measuring points obtain for each survey is available for only a limited number of stations.

Adjustment for Errors in Precipitation Measurement

A review of the literature on techniques for adjusting precipitation for errors due to wind effect and other factors has been accomplished. Adjustment procedures for use in the current project have been developed but have not been finalized. A summary, discussing the adjustment techniques for use in this project, is presented in **Attachment C**. The basic procedures were developed by Hydex in a study for the Environmental Protection Agency (EPA) during which precipitation records for specific locations in northeast US and southeast Canada were adjusted for errors due to wind action at the time precipitation occurred. Most of the Figures in Attachment C were developed during the EPA study using synoptic stations records in the United States and Canada. 1/ Records for the Canadian stations were furnished by AES and considerable advice and information for the development of the procedures were received from Barry Goodison of AES.

Quality of Snow Survey and Precipitation Measurements

All snow survey records for the Lake Ontario drainage areas in Canada and the United States have been obtained and are on the Hydex computer. These records have been checked with published records. Snow density values were computed for each snow survey and were reviewed to insure that the values were consistent with those of surrounding stations and for the climate conditions. Information on locations of ground snow surveys have been obtained and tables presenting this information are in Attachments A and B.

The consistency of the snow survey records will be checked using techniques similar to those being used for precipitation records. However, evaluation of the quality of the records for representing areal average snow conditions is difficult to accomplished. The value of the ground snow survey records is determined to a major

1/ "Precipitation Data Analysis for Evaluation of Regional Acid Rain Deposition Simulation Models," Final Report, Hydex Corporation to EPA for Modeling Subgroup, Atmospheric Sciences and Analysis Workgroup 2, Under MOI signed August 5, 1980, by United States and Canada. March 1982.

extent by the exposure conditions for the site of the measurement(s). Airborne snow survey records (that are considered to be more representative of areal conditions) will be used during Phase II and Phase III of the project to determine how representative the ground records are for computing areal averages of the water equivalent of the snow cover. Comparison of ground snow survey records with airborne gamma radiation survey records has been postponed until additional records of the airborne surveys are available.

Evaluation of the quality of the precipitation measurements (rain and snowfall) has been initiated. Double mass plots of the winter measurement of precipitation have been prepared. A brief discussion on this work is presented in **Attachment D.**

PAPER FOR IAGLR MEETING

An invitation was received to present an invited paper at the International Association for Great Lake Research, IAGLR, annual conference to be held in Buffalo, New York, June 2-6, 1991. The paper "Evaluation of Ground and Airborne Data for Snowmelt Forecasting for Lake Ontario Basin," has been accepted and will be presented in the "Forecast and Prediction Systems" session on June 3, 1991.

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ATTACHMENT A

UNITED STATES DATA BASE

CLIMATE RECORDS

Daily Precipitation Records

Daily precipitation values from 1955-1990 for the 93 stations listed in **Attachment A-1** are on hand at Hydex. The records were obtained primarily from the NOAA Library in Rockville, Maryland and the Washington NWS offices.

Monthly values were computed from the daily values and put in tabular form with annual, Oct-Apr and May-Sep totals and with 30-yr monthly and seasonal average values. Missing monthly values for the period 1961 to 1990 for longer record stations were estimated from nearby stations. In the publication of the daily precipitation records in the Monthly Climatological Bulletins, the US practice is to have a "M" appended to the monthly total if 1-9 daily values are missing. If 10 or more days are missing no monthly total is published. Missing data for partial periods in 1989 and 1990 were estimated based on average relationships with nearby stations. Some monthly totals, prior to 1989, that were computed from the records of daily precipitation values available on CD ROMS have periods of missing data. These records need to be checked and values for these periods estimated from nearby stations. A sample of a monthly data form, containing the average values and dates of months with missing records that were estimated from nearby stations, is shown in **Attachment A-2**.

The standard precipitation gage at climate stations of the NWS has a collector of 8-inch (20.3 cm) diameter that is mounted with its orifice about three feet above the ground. This is the gage used to collect measurements of the daily amount of precipitation (rain and snowfall) at about 90 cooperative weather stations (daily climate stations) in and adjacent to the Lake Ontario drainage area. This is a manual gage with an inside tube (the measuring tube) that is 1/10 the area of the larger collector and a funnel on top of the overflow can of the gage. Rainfall is measured by inserting a measurement stick in the inside tube and measuring the amount of precipitation from the scale on the measurement stick. When snowfall is anticipated, the inside tube and the funnel are removed and the snowfall allowed to fall directly into the large overflow can. The amount of snowfall is measured by allowing the snow in the overflow can to melt or by pouring into the overflow can a measured amount of warm water and pouring the liquid into the measuring tube to measure the snowfall as you do for rain (correcting for the warm water added if this was done).

Hourly Precipitation

Records of daily amounts of precipitation at hourly precipitation stations (recording precipitation stations) required for use in initial evaluation analyses have been obtained. Records of daily precipitation for other hourly stations are available at the NOAA Library or NWS offices.

Several different recording gages are used at about 30 recording stations (most of which are also daily climate stations) in and near Lake Ontario for which hourly amounts of precipitation are published. The three most common recording gages are the tipping bucket, the weighing-type gage (often referred to as the universal gage), and a punched tape recording gage (the Fischer-Porter). All recording gages are mounted with the gage orifice about four to five feet above ground, except when occasionally mounted on roofs of buildings. Windshields (alter type) in the Lake Ontario basin are installed almost exclusively on gages at synoptic weather stations.

Temperature Records

Temperature records are available for a large number of stations listed in Attachment A-1 (most of these stations also report daily precipitation, snowfall, snow on the ground, and a few report water equivalent of snow on the ground). Sample records have been obtained for those stations required for demonstration purposes. Records for all other stations are available at the NOAA Library or NWS offices.

Snowfall

Records of daily snowfall for some of the climate stations have been obtained. Records for remainder of basin stations are available from the NOAA Library or NWS offices.

Snow on Ground

A sample set of records of daily snow on ground data have been obtained. Records for rest of stations that record snow on ground are available from the NOAA Library or NWS offices.

Station History Information

Copies of forms containing station histories information for stations listed in Attachment A have been obtained and on file at Hydex. This constituted a major undertaking. However, station history information is now available for all precipitation stations (daily, hourly and synoptic) in and immediately adjacent to the US drainage area. These station history files were obtained from micro-fiche at the NOAA Library and by copying original forms at NWS for the last few years. This was accomplished at this time since experience has shown that the forms for the last few years are often unavailable for long periods of time when the forms for the latest years are sent to be placed on micro-fiche.

Wind

Daily wind movement records for Syracuse, New York, have been obtained from NWS files and are on the Hydex's computer. Tim Hunter, Great Lakes Environmental Research Laboratory (GLERL), has furnished daily wind records for the last few years for most synoptic stations in Canada and in the US. He has also furnished daily wind records for the Watertown Airport station for the period 1949-64 and for the last four months of 1988. Daily wind records for the Watertown Airport station were obtained for the period 1989-1990 from the Detroit Office of the COE.

SNOW SURVEYS

Snow Surveys (Ground)

Keith Eggleston, Northeast Climate Center, Cornell University has furnished a tabulation of historical snow course records (from 1957-1990) for the State of New York. The first and last pages of the table, US Snow Surveys Data, Lake Ontario Basin, listing all records for stations in study area is shown in **Attachment A-3**. A list of snow survey locations is presented in the table, Snow Survey Stations in US, Lake Ontario Basin, shown in **Attachment A-4**.

Snow Surveys (Airborne Gamma)

Airborne gamma radiation surveys of the water equivalent of the snow were obtained from Thomas Carroll (NWS) for 42 flight lines flown on March 1-3, 1990, using the NWS Airborne Gamma Radiation System. Earlier surveys were made over the Lake Ontario basin by the NWS during IFYGL in 1973 and 1974 but are not usable since the airborne gamma radiation system has changed.

Information as to location of each flight line, digitized longitude and latitude, for the beginning and end points of the 42 established flight lines was received. A map showing the flight lines has also been furnished by Tom Carroll (NWS).

US STATIONS, LAKE ONTARIO DRAINAGE BASIN

ATTACHMENT A-1

STATE-STATION NEW YORK	30 YR DATA 1/	EXP 2/	NUMBER	LAT	LONG	ELEV FT MSL	PERIOD OF RECORD /3	TYPE DATA	% /4	WIND SENSOR
ALBION 3 ENE			30-0055	43.25	78.13	510	5/1948 - 12/1988	PP24	74	
							5/1948 - 12/1988	SNOF	73	
							5/1948 - 12/1988	SNOG	70	
ALFRED	30		30-0085	42.25	77.80	1740	1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	99	
							1/1926 - 12/1988	SNOG	99	
ANGELICA	30		30-0183	42.30	78.03	1420	1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	93	
							1/1926 - 12/1988	SNOG	88	
ARCADE			30-0220	42.53	78.42	1490	5/1948 - 12/1988	PP24	93	
							5/1948 - 12/1988	SNOF	93	
							5/1948 - 12/1988	SNOG	93	
AURORA RESEARCH FARI	30		30-0331	42.73	76.65	830	11/1958 - 12/1988	PP01	98	
							11/1956 - 12/1988	PP24	99	
							11/1956 - 12/1988	SNOF	98	
							11/1956 - 12/1988	SNOG	98	
AUBURN 2 NE			30-0321	42.92	76.53	770	1/1926 - 11/1987	PP24	83	
							1/1926 - 11/1987	SNOF	83	
							1/1926 - 11/1987	SNOG	79	
							2/1989 - 12/1990	PP24	100	
AVON			30-0343	42.95	77.73	560	5/1948 - 12/1988	PP24	80	
							5/1948 - 12/1988	SNOF	62	
							5/1948 - 12/1988	SNOG	63	
BALDWINSVILLE	30		30-0379	43.15	76.33	380	5/1948 - 12/1988	PP24	97	
							5/1948 - 12/1988	SNOF	89	
							5/1948 - 11/1988	SNOG	65	
BARNES CORNERS			30-0424	43.82	75.80	1520	11/1979 - 12/1988	PP24	93	
							11/1979 - 12/1988	SNOF	94	
							11/1979 - 12/1988	SNOG	93	
BATAVIA	30		30-0443	43.00	78.18	900	12/1984 - 12/1988	PP01	92	
							5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	98	
							5/1948 - 12/1988	SNOG	94	
BATH			30-0448	42.33	77.33	1110	8/1953 - 12/1988	PP24	96	
							8/1953 - 12/1988	SNOF	95	
							8/1953 - 12/1988	SNOG	95	
BEAVER FALLS	30		30-0500	43.88	75.43	740	5/1948 - 12/1988	PP24	98	
							5/1948 - 11/1988	SNOF	92	
							5/1948 - 12/1988	SNOG	91	
BENNETTS BRIDGE	30		30-0608	43.53	75.95	660	5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	98	
							5/1948 - 12/1988	SNOG	94	
BIG MOOSE 3 SE	30		30-0668	43.80	74.87	1760	5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	91	
							5/1948 - 12/1988	SNOG	56	
BOLIVAR			30-0766	42.07	78.17	1580	5/1948 - 12/1988	PP01	90	
							5/1948 - 12/1988	PP24	55	
							5/1948 - 12/1988	SNOF	55	
							5/1948 - 12/1988	SNOG	55	
BOONVILLE 2 SSW	30		30-0785	43.45	75.35	1580	10/1949 - 12/1988	PP01	90	
							10/1949 - 12/1988	PP24	99	
							10/1949 - 12/1988	SNOF	99	
							10/1949 - 12/1988	SNOG	99	
BREWERTON LOCK 23	30		30-0870	43.23	76.20	380	5/1948 - 12/1988	PP24	99	
							5/1948 - 12/1988	SNOF	95	
							5/1948 - 12/1988	SNOG	75	
BROCKPORT 2 NW	30		30-0937	43.25	77.97	410	2/1950 - 12/1988	PP24	98	
							2/1950 - 12/1988	SNOF	96	
							2/1950 - 12/1988	SNOG	92	
BUFFALO WSFO AP	30	wnd	30-1012	42.93	78.73	710	5/1948 - 12/1988	PP01	100	YES
							1/1922 - 12/1988	PP24	99	
							1/1922 - 12/1988	SNOF	99	
							1/1922 - 12/1988	SNOG	99	
							1/1979 - 12/1988	SNWE	74	
CAMDEN			30-1110	43.33	75.75	510	5/1948 - 12/1988	PP24	91	
							5/1948 - 12/1988	SNOF	87	
							5/1948 - 12/1988	SNOG	59	
CANANDAIGUA 3 S	30		30-1152	42.85	77.28	720	5/1948 - 12/1988	PP24	99	
							5/1948 - 12/1988	SNOF	71	
CANDOR			30-1168	42.23	76.35	900	5/1948 - 12/1988	PP24	95	
							5/1948 - 12/1988	SNOF	95	
							5/1948 - 12/1988	SNOG	95	

US STATIONS, LAKE ONTARIO DRAINAGE BASIN

CANTON	30	30-1185	44.58	75.17	410	5/1948 - 12/1988	PP01	94
						1/1922 - 12/1988	PP24	98
						1/1922 - 12/1988	SNOF	97
						1/1922 - 12/1988	SNOG	96
CAYUGA LOCK 1	30	30-1265	42.95	76.73	380	10/1979 - 12/1988	PP01	88
						5/1948 - 12/1988	PP24	98
						5/1948 - 12/1988	SNOF	90
						5/1948 - 12/1988	SNOG	60
CLYDE LOCK 26	30	30-1580	43.07	76.83	390	5/1948 - 12/1988	PP24	99
						5/1948 - 12/1988	SNOF	92
						5/1948 - 11/1988	SNOG	59
COLTON 2 N		30-1664	44.58	74.95	580	5/1948 - 12/1987	PP24	98
						5/1948 - 10/1987	SNOF	45
						5/1948 - 10/1987	SNOG	46
CORTLAND	30	30-1799	42.60	76.18	1130	5/1948 - 12/1988	PP24	99
						5/1948 - 12/1988	SNOF	99
						5/1948 - 12/1988	SNOG	99
DANSVILLE	30	30-1974	42.57	77.70	690	10/1941 - 12/1988	PP24	84
						10/1941 - 12/1988	SNOF	84
						10/1941 - 12/1988	SNOG	84
DANSVILLE CAA AIRPORT		30-1979	42.58	77.72	650	5/1948 - 12/1988	PP01	100
						5/1948 - 12/1953	PP24	99
						5/1948 - 12/1953	SNOF	96
						5/1948 - 12/1953	SNOG	96
FRANKLINVILLE 1 SSW	30	30-3025	42.33	78.47	1580	7/1949 - 12/1988	PP24	95
						7/1949 - 12/1988	SNOF	90
						7/1949 - 12/1988	SNOG	93
FREEVILLE 2 NE	30	30-3050	42.53	76.32	1080	6/1948 - 11/1988	PP24	93
						6/1948 - 11/1988	SNOF	93
						6/1948 - 11/1988	SNOG	93
FRIENDSHIP 7 SW	30	30-3065	42.13	78.23	1640	1/1969 - 12/1988	PP24	99
						1/1969 - 12/1988	SNOF	99
						1/1969 - 12/1988	SNOG	99
GANNETT HILL		30-3124	42.70	77.40	1950	7/1971 - 12/1988	PP24	95
						7/1971 - 12/1988	SNOF	90
						7/1971 - 12/1988	SNOG	83
GENEVA RESEARCH FARM	30	30-3184	42.88	77.03	720	5/1966 - 12/1988	PP01	95
						1/1969 - 12/1988	PP24	99
						1/1969 - 12/1988	SNOF	100
						1/1969 - 12/1988	SNOG	99
GOUVERNEUR	30	30-3346	44.33	75.48	460	5/1948 - 12/1988	PP24	99
						5/1948 - 12/1988	SNOF	99
						5/1948 - 12/1988	SNOG	99
GRIFFISS FIELD	30	30-3507	43.23	75.42	490	6/1961 - 12/1988	PP24	99
						6/1961 - 12/1988	SNOF	99
						6/1961 - 12/1988	SNOG	96
HASKINVILLE		30-3722	42.42	77.57	1620	5/1948 - 12/1988	PP24	97
						5/1948 - 12/1988	SNOF	97
						5/1948 - 12/1988	SNOG	97
HECTOR		30-3766	42.50	76.88	780	5/1967 - 12/1988	PP24	86
						5/1967 - 12/1988	SNOF	90
						5/1967 - 12/1988	SNOG	86
HEMLOCK	30	30-3773	42.78	77.62	900	1/1926 - 12/1988	PP24	98
						1/1926 - 11/1988	SNOF	84
						1/1926 - 11/1988	SNOG	83
HIGHMARKET	30	30-3851	43.57	75.52	1760	8/1968 - 12/1988	PP01	91
						5/1948 - 12/1988	PP24	100
						5/1948 - 12/1988	SNOF	93
						5/1948 - 12/1988	SNOG	58
HINCKLEY		30-3889	43.32	75.12	1190	5/1948 - 12/1988	PP24	97
						5/1948 - 12/1988	SNOF	93
						5/1948 - 12/1988	SNOG	60
HORNELL ALMOND DAM	30	30-3983	42.35	77.70	1330	2/1950 - 12/1988	PP01	95
						2/1950 - 12/1988	PP24	93
						2/1954 - 12/1988	SNOF	97
						2/1954 - 12/1988	SNOG	97
ITHACA CORNELL UNIV	30	30-4174	42.45	76.45	960	5/1948 - 12/1988	PP01	96
						1/1926 - 12/1988	PP24	99
						2/1926 - 12/1988	SNOF	96
						3/1926 - 12/1988	SNOG	97
LEWISTON 3 SE		30-4717	43.13	78.97	630	11/1987 - 12/1988	PP24	99
						11/1987 - 12/1988	SNOF	99
						11/1987 - 12/1988	SNOG	98
LOCKE 2 W	30	30-4836	42.67	76.47	1200	5/1948 - 12/1988	PP24	99
						5/1948 - 11/1988	SNOF	45
						5/1948 - 11/1988	SNOG	38

LOCKPORT 2 NE	30		30-4844	43.18	78.65	520	1/1926 - 12/1988	PP24	98	
							1/1926 - 12/1988	SNOF	98	
							1/1926 - 12/1988	SNOG	98	
LOCKPORT 4 NE	30		30-4849	43.20	78.63	440	6/1961 - 12/1988	PP24	99	
							6/1961 - 12/1988	SNOF	99	
							6/1961 - 12/1988	SNOG	99	
LOWVILLE	30		30-4912	43.80	75.48	860	3/1987 - 12/1988	PP01	94	
							1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	99	
							5/1926 - 12/1988	SNOG	69	
LYONS FALLS	30		30-4944	43.62	75.37	800	5/1948 - 12/1988	PP24	97	
							5/1948 - 12/1988	SNOF	92	
MACEDON			30-4952	43.07	77.30	470	5/1948 - 12/1988	PP24	72	
							5/1948 - 12/1988	SNOF	66	
							5/1948 - 12/1988	SNOG	42	
MAYS POINT LOCK 25	30		30-5171	43.00	76.77	400	5/1948 - 12/1988	PP24	98	
							5/1948 - 11/1988	SNOF	76	
							5/1948 - 11/1988	SNOG	59	
MOUNT MORRIS 2 W	30		30-5597	42.73	77.90	880	6/1950 - 12/1988	PP01	93	
							8/1948 - 12/1988	PP24	97	
							8/1948 - 11/1988	SNOF	92	
							8/1948-12/1988	SNOG	95	
NEWARK	30		30-5679	43.05	77.08	430	5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	68	
							5/1948 - 11/1988	SNOG	51	
NEW LONDON LOCK 22	30		30-5751	43.22	75.65	400	5/1948 - 12/1988	PP24	99	
							5/1948 - 11/1988	SNOF	76	
							5/1948 - 11/1988	SNOG	58	
NORFOLK	30		30-5869	44.80	75.00	230	5/1948 - 12/1988	PP24	99	
							5/1948 - 12/1988	SNOF	96	
							5/1948 - 12/1988	SNOG	80	
NORTH TONAWANDA			30-6047	43.08	78.75	6080	9/1982 - 12/1988	PP24	98	
							9/1982 - 12/1988	SNOF	98	
							9/1982 - 12/1988	SNOG	98	
OGDENSBURG HOSP 3 NE	30		30-6164	44.73	75.45	280	1/1926 - 12/1988	PP24	96	
							1/1926 - 12/1988	SNOF	85	
							1/1926 - 12/1988	SNOG	72	
OLD FORGE	30		30-6184	43.70	74.98	1720	5/1948 - 12/1988	PP01	93	
							5/1948 - 12/1988	PP24	94	
							9/1948 - 12/1988	SNOF	90	
							9/1948 - 12/1988	SNOG	89	
OSWEGO EAST	30		30-6314	43.47	76.50	350	5/1948 - 12/1988	PP01	95	
							1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	99	
							1/1926 - 12/1988	SNOG	98	
PAVILION	30		30-6464	42.88	78.03	940	11/1956 - 12/1988	PP01	91	
							9/1956 - 12/1988	PP24	99	
							9/1956 - 12/1988	SNOF	99	
							9/1956 - 12/1988	SNOG	99	
PENN YAN 8 W	30		30-6517	42.67	77.18	1000	6/1984 - 12/1988	PP24	93	
							6/1984 - 12/1988	SNOF	98	
							6/1984 - 12/1988	SNOG	92	
PORTAGEVILLE	30		30-6745	42.57	78.05	1120	6/1956 - 12/1988	PP24	97	
							6/1956 - 12/1988	SNOF	74	
							6/1956 - 12/1988	SNOG	74	
PRATTSBURG 2 NW			30-6831	42.53	77.30	1940	/1948-10/1986	PP24	99	
							/1948-10/1986	SNOF	98	
							/1948-10/1986	SNOG	98	
PRATTSBURG			30-6833	42.52	77.27	1470	1/1988 - 12/1986	PP24	100	
							1/1988 - 12/1986	SNOF	100	
							1/1988 - 12/1986	SNOG	100	
PULASKI			30-6867	43.57	76.13	360	5/1948 - 7/1949	PP01	97	
							5/1948 - 12/1988	PP24	60	
							5/1948 - 12/1988	SNOF	61	
							5/1948 - 12/1988	SNOG	49	
RECTORS CORNERS			30-6965	43.75	75.58	1810	1/1987-12/1988	PP24	9	
							1/1987-12/1988	SNOF	100	
							1/1987-12/1988	SNOG	99	
ROCHESTER WB AP	30	wnd	30-7167	43.12	77.67	550	5/1948 - 12/1988	PP01	100	YES
							1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	99	
							1/1926 - 12/1988	SNOG	99	
							1/1979 - 12/1988	SNWE	74	
RUSHFORD	30		30-7329	42.40	78.25	1500	4/1954 - 11/1988	PP24	96	
							4/1954 - 11/1988	SNOF	89	
							4/1954 - 11/1988	SNOG	73	

US STATIONS, LAKE ONTARIO DRAINAGE BASIN

SKANEATELES	30		30-7780	42.95	76.43	880	5/1948 - 12/1988	PP24	99	
							5/1948 - 12/1988	SNOF	99	
							5/1948 - 12/1988	SNOG	99	
SODUS 2 SSW	30		30-7842	43.22	77.07	440	5/1948 - 12/1988	PP24	97	
							5/1948 - 12/1988	SNOF	91	
							5/1948 - 12/1988	SNOG	92	
STILLWATER RESERVOIR	30		30-8248	43.88	75.03	1700	5/1948 - 12/1988	PP01	97	
							5/1948 - 12/1988	PP24	99	
							5/1948 - 12/1988	SNOF	93	
							5/1948 - 12/1988	SNOG	64	
STONY POINT 2 E		wnd	30-8290	43.83	76.27	260	4/1978 - 12/1988	PP01	77	
SYRACUSE WB AP	30		30-8383	43.12	76.12	420	5/1948 - 12/1988	PP01	100	YES
							1/1922 - 12/1988	PP24	99	
							1/1922 - 12/1988	SNOF	99	
							1/1922 - 12/1988	SNOG	99	
							1/1979 - 12/1988	SNWE	76	
TRENTON FALLS	30		30-8578	43.27	75.15	800	5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	68	
							5/1948 - 11/1988	SNOG	53	
UTICA CAA AP	30		30-8737	43.15	75.38	710	1/1951 - 10/1952	PP01	92	
							12/1950 - 12/1988	PP24	96	
							12/1950 - 12/1988	SNOF	96	
							12/1950 - 12/1988	SNOG	96	
UTICA 2 SE			30-8739	43.08	75.18	500	10/1952 - 12/1988	PP01	88	
							8/1948 - 12/1988	PP24	89	
							8/1948 - 12/1988	SNOF	87	
							8/1948 - 12/1988	SNOG	87	
VICTOR			30-8839	42.98	77.42	640	5/1948 - 12/1988	PP01	99	
							5/1948 - 12/1988	PP24	12	
							6/1948 - 12/1988	SNOF	8	
							6/1948 - 12/1988	SNOG	8	
WANAKENA RANGER SCH	30		30-8944	44.15	74.90	1510	5/1948 - 12/1988	PP01	92	
							1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	99	
							1/1926 - 12/1988	SNOG	98	
WARSAW 5 SW			30-8962	42.68	78.20	1720	10/1978 - 5/1981	PP01	56	
							11/1952 - 12/1988	PP24	93	
							11/1952 - 12/1988	SNOF	91	
							12/1952 - 12/1988	SNOG	91	
WATERLOO	30		30-8987	42.90	76.87	450	5/1948 - 12/1988	PP24	98	
							5/1948 - 12/1988	SNOF	92	
							5/1948 - 11/1988	SNOG	64	
WATERTOWN	30		30-9000	43.97	75.87	500	5/1948 - 12/1988	PP01	97	
							1/1926 - 12/1988	PP24	99	
							1/1926 - 12/1988	SNOF	97	
							1/1926 - 12/1988	SNOG	90	
WATERTOWN FAA AP			30-9005	44.00	76.02	320	5/1949 - 4/1951	PP01	81	YES
							5/1949 - 12/1988	PP24	94	
							5/1949 - 12/1988	SNOF	95	
							5/1949 - 12/1988	SNOG	95	
WELLESLEY ISLAND			30-9055	44.30	76.03	280	7/1974 - 12/1988	PP24	99	
							7/1974 - 12/1988	SNOF	97	
							7/1974 - 12/1988	SNOG	98	
WELLSVILLE	30		30-9072	42.12	77.95	1510	12/1955 - 12/1988	PP01	95	
							6/1956 - 12/1988	PP24	94	
							6/1956 - 12/1988	SNOF	93	
							6/1956 - 12/1988	SNOG	92	
WELLSVILLE 4 NNW			30-9076	42.17	77.98	1460	9/1975 - 12/1988	PP24	95	
							9/1975 - 12/1988	SNOF	93	
							9/1975 - 12/1988	SNOG	93	
WHITESVILLE	30		30-9425	42.03	77.77	1720	2/1954 - 12/1988	PP24	99	
							2/1954 - 12/1988	SNOF	99	
							2/1954 - 12/1988	SNOG	99	
WILSON 2 NE			30-9507	43.32	78.80	270	5/1948 - 12/1988	PP24	97	
							5/1948 - 11/1988	SNOF	69	
							5/1948 - 11/1988	SNOG	65	
WISCOY 1 E			30-9533	42.50	78.07	1140	5/1948 - 12/1988	PP24	93	
							5/1948 - 12/1988	SNOF	80	
							5/1948 - 12/1988	SNOG	75	
WOLCOTT			30-9544	43.22	76.82	370	5/1948 - 12/1988	PP24	90	
							5/1948 - 12/1988	SNOF	75	
							5/1948 - 11/1988	SNOG	54	

PENNSYLVANIA								
GALETON	30	36-3130	41.73	77.63	1370	5/1948 - 12/1988	PP24	99
						5/1948 - 12/1988	SNOF	99
						5/1948 - 12/1988	SNOG	98
RAYMOND	30	36-7310	41.87	77.87	2200	5/1948 - 12/1988	PP01	90
						6/1948 - 12/1988	PP24	90
						2/1954 - 12/1988	SNOF	80
						2/1954 - 12/1988	SNOG	84
SABINSVILLE 3 SE		36-7730	41.83	77.47	200	10/1951 - 1/1952	PP01	31
						12/1969 -12/1988	PP24	98
						4/1970 -11/1988	SNOF	76
						3/1970 - 12/1988	SNOG	96
WESTFIELD 5 S		36-9490	41.98	77.57	1880	11/1981 - 12/1988	PP01	73
						10/1981 - 10/1988	PP24	78
						10/1981 - 10/1988	SNOF	71
						10/1981 - 10/1988	SNOG	65

NOTES

1. Most information from the Climatic Data files (CNIFINDX) for the States of New York and Pennsylvania obtained from the Office of Hydrology, National Weather Service, NOAA, Silver Spring, Maryland.
2. Records of daily precipitation values (PP24) for all listed stations, for the period from January 1955 through 1990, were obtained from the files of the NOAA Library, Rockville, Maryland and are stored on Hydex's computer systgem.
3. Records of snowfall (SNOF), snow on the ground (SNOG) and hourly precipitation data (PP01) and snow water equivalent (SNWE) are available at the NOAA Library, Rockville, Maryland but have not been transfered to Hydex files.

FOOTNOTES

1/ For those stations marked 30, thirty-year normals (annual, October-April and May-September), based on the period 1961-1990, have been computed. Missing data for these stations have been estimated from nearby stations.

2/ Exposure of prcipitation gage as defined by Brown and Peck (AGU 1962). WP - Well protected. PRO - Protected. FWP - Fairly well protected. MW - Moderately Windy. WND - Windy. VWND - Very windy. OPRO = Over protected.

3/ Records for years 1955-1988 were obtained from the CD-ROM files (Climatedata) at NOAA Library, Rockville, Maryland. Records for years 1989 and 1990 were processed from Climatic data publicationas and are incluced in Hydex files.

4/ Overall percentage of non-missing data for period of record indicated in previous column.

Hydex, MAY 1991

ATTACHMENT A-2

BEAVER FALLS, NY MONTHLY

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL	OCT-APR	MAY-SEP
1955	1.01	1.39	3.54	2.15	2.59	1.60	2.29	3.67	2.30	5.83	1.90	0.90	29.17		12.45
1956	1.20	2.17	2.56	2.30	3.11	1.82	2.10	3.12	3.86	1.85	3.41	2.15	29.65	16.86	14.01
1957	1.82	1.13	1.32	1.28	3.22	4.70	3.26	0.81	4.42	1.09	2.42	1.98	27.45	12.96	16.41
1958	1.62	1.97	0.31	1.60	3.13	4.63	6.09	5.74	4.67	3.24	2.94	1.30	37.24	10.99	24.26
1959	3.48	2.93	1.77	2.11	3.18	1.89	2.95	5.43	2.40	5.24	3.70	4.38	39.46	17.77	15.85
1960	2.15	4.42	0.33	2.30	4.25	4.52	2.23	2.20	1.69	3.28	1.55	1.75	30.67	22.52	14.89
1961	1.67	2.42	1.94	5.13	2.73	3.99	2.24	3.56	1.70	3.22	3.00	2.63	34.23	17.74	14.22
1962	3.34	2.12	1.03	3.47	2.82	1.45	5.19	6.34	5.44	2.56	1.42	2.46	37.64	18.81	21.24
1963	2.51	1.76	3.05	2.77	3.25	3.32	2.31	5.88	0.94	0.38	5.51	2.66	34.34	16.53	15.70
1964	3.11	0.82	3.27	2.16	3.50	1.14	2.21	3.22	0.79	1.78	2.97	2.82	27.79	17.91	10.86
1965	1.89	2.80	1.35	2.77	1.14	3.37	0.97	5.32	3.78	3.90	5.16	1.59	34.04	16.38	14.58
1966	2.45	2.48	2.52	0.87	1.55	1.92	2.10	3.70	3.13	1.30	1.82	4.89	28.73	18.97	12.40
1967	1.94	1.75	0.32	2.94	2.88	1.76	3.79	5.16	2.88	3.98	4.52	1.35	33.27	14.96	16.47
1968	1.66	1.08	2.40	2.21	4.13	3.41	1.63	2.01	4.20	4.64	4.83	4.11	36.31	17.20	15.38
1969	2.48	0.79	1.47	4.46	5.12	6.25	2.11	2.41	2.18	2.27	3.68	3.57	36.79	22.78	18.07
1970	1.69	2.30	1.91	2.78	3.86	4.26	3.77	4.48	3.87	5.37	3.79	5.16	43.24	18.20	20.24
1971	3.52	4.64	5.44	1.54	3.38	2.22	4.17	3.70	3.63	1.35	3.22	2.69	39.50	29.46	17.10
1972	1.70	4.70	3.75	2.30	4.61	6.82	6.07	2.52	1.90	2.55	4.25	4.75	45.92	19.71	21.92
1973	2.72	2.26	2.26	5.61	4.38	3.44	3.46	1.69	3.71	3.08	3.56	5.13	41.30	24.40	16.68
1974	2.90	1.65	4.00	3.05	3.99	3.66	3.15	2.81	4.11	1.51	5.27	3.71	39.81	23.37	17.72
1975	2.94	3.37	2.78	1.93	1.34	2.85	7.35	4.45	6.71	3.29	3.92	3.68	44.61	21.51	22.70
1976	5.73	1.53	3.22	2.69	5.82	7.73	2.66	3.88	4.28	6.06	1.30	2.24	47.14	24.06	24.37
1977	2.59	1.37	4.45	2.83	1.26	1.65	2.67	7.72	5.47	4.50	5.59	5.65	45.75	20.84	18.77
1978	5.44	0.63	1.35	2.16	1.11	2.66	1.14	2.94	5.32	2.86	1.64	3.60	30.85	25.32	13.17
1979	3.52	1.48	0.97	3.28	3.75	1.11	0.91	5.85	5.15	3.13	4.92	1.77	35.84	17.35	16.77
1980	1.45	0.84	3.33	5.38	0.89	4.01	6.42	2.16	3.78	4.87	3.49	2.66	39.28	20.82	17.26
1981	0.72	3.90	1.30	2.87	3.16	2.12	4.89	4.57	5.13	4.71	2.14	1.75	37.26	19.81	19.87
1982	3.38	2.27	2.65	2.21	2.14	5.24	2.14	4.52	5.26	2.74	4.11	2.61	39.27	19.11	19.30
1983	1.64	1.11	1.85	5.27	3.48	1.92	1.61	8.82	2.34	3.10	3.88	9.29	44.32	19.33	18.17
1984	1.66	4.23	1.62	4.20	4.64	2.27	2.42	4.32	2.59	1.00	2.91	4.52	36.38	27.98	16.24
1985	3.31	3.08	2.57	2.46	2.48	4.50	2.31	2.64	4.74	3.65	5.84	4.20	41.78	19.85	16.67
1986	3.00	1.75	2.88	1.81	3.21	4.89	5.47	3.22	3.38	3.38	3.16	3.03	39.18	23.13	20.17
1987	3.93	0.64	1.50	1.97	1.82	4.80	3.23	2.82	5.14	3.50	3.79	2.58	35.72	17.61	17.81
1988	0.93	3.57	1.29	3.04	2.96	1.74	2.73	4.31	2.46	5.65	4.46	1.57	34.71	18.70	14.20
1989	1.70	1.33	3.51	2.21	4.38	3.19	2.65	4.47	5.33	3.48	6.26	1.60	40.11	20.43	20.02
1990	3.37	3.38	2.11	4.86	5.19	5.04	3.89	2.42	2.73	6.44	2.45	4.50	46.38	25.06	19.27
AVG	**2.63**	**2.20**	**2.40**	**3.04**	**3.17**	**3.42**	**3.19**	**4.06**	**3.74**	**3.34**	**3.76**	**3.43**	**38.38**	**20.58**	**17.58**
EST	3/64	8/83	10/83	11/83	4/85										
M EST NONE															

US SNOW SURVEY DATA, LAKE ONTARIO BASIN

	A	B	C	D	E	F	G	H
1							**ATTACHMENT A- 3**	
2	DATA FOR BASIN C			STATE OF NEW YORK				
3	Station	Date	Period *	Snow Depth	Water Equiv	Notes		
4				INCHES	INCHES 1/	2/		
5	C01 CANADICE AND HEMLOCK LAKES, N.Y.							
6	C01	600104	1	2.7	0.6	A		
7	C01	600201	2	4.3	1.17	A		
8	C01	600301	3	16.7	3.81	A		
9	C01	600314	4	16.9	4.48	A		
10	C01	610103	1	14.2	2.03	A		
11	C01	610131	2	10.1	2.46	A		
12	C01	610227	3	3	0.9	A		
13	C01	610313	4	3.9	0.91	A		
14	C01	620109	1	0.4	0.1	A		
15	C01	620205	2	0.2	0.03	A		
16	C01	620505	3	5.2	1.85	A		
17	C01	620319	4	2.3	0.74	A		
18	C01	630107	1	7.6	1.84	A		
19	C01	630205	2	11.7	3.23	A		
20	C01	630304	3	13.2	4.42	A		
21	C01	630318	4	5.9	1.87	A		
22	C01	640107	1	9.1	2.09	A		
23	C01	640203	2	3.2	0.81	A		
24	C01	640316	4	1.5	0.73	A		
25	C01	650104	1	5.1	1.06	A		
26	C01	650201	2	8.9	1.45	A		
27	C01	650302	3	1.6	0.37	A		
28	C01	650315	4	4.3	0.44	A		
29	C01	660103	1	0	0	A		
30	C01	660121	2	19.2	4.21	A		
31	C01	670109	1	1.8	0.46	A		
32	C01	670130	2	6.8	0.89	A		
33	C01	670227	3	3.9	0.89	A		
34	C01	670313	4	0.8	0.22	A		
35	C01	680304	3	4.6	0.69	A		
36	C01	680318	4	0.9	0.3	A		
37	C01	690107	1	2.7	0.54	A		
38	C01	690204	2	2.1	0.39	A		
39	C01	690304	3	5.3	1.31	A		
40	C01	690317	4	5.5	1.62	A		
41	C01	690331	5	0.4	0.05	A		
42	C01	700205	2	10.3	2.11	A		
43	C01	700304	3	8.3	2.82	A		
44	C01	700319	4	7.5	1.67	A		
45	C01	700401	5	14.1	0.85	A		
46	C01	710201	2	7.6	2.28	A		
47	C01	710304	3	6.2	3.19	A		
48	C01	710315	4	6.4	2.57	A		
49	C01	710329	5	2.7	0.97	A		
50	C01	710413	6	0	0	A		
51	C01	720103	1	3.7	0.88	A		
52	C01	720201	2	3.3	0.44	A		
53	C01	720228	3	15.2	3.68	A		
54	C01	720314	4	5.8	2.02	A		
55	C01	720327	5	2.4	0.68	A		
56	C01	730102	1	0	0	A		
57	C01	730130	2	3.9	0.35	A		
58	C01	730226	3	7.4	2.08	A		
59	C01	730312	4	0	0	A		
60	C01	730326	5	0	0	A		
61	C01	740109	1	1.8	0.25	A		
62	C01	740204	2	4.4	0.58	A		
63	C01	740305	3	0	0	A		
64	C01	740320	4	2.6	0.63	A		
65	C01	740403	5	0	0	A		
66	C01	750108	1	8.7	1.9			
67	C01	750204	2	3.6	0.54			
68	C01	750304	3	3.2	0.79			
69	C01	750319	4	0	0			

	A	B	C	D	E	F	G	H
70	G38	890103	1	8.2	1			
71	G38	890131	2	9	2			
72	G38	890227	3	10.7	2.7			
73	G38	890314	4	10.8	3.4			
74	G38	890328	5	10.4	3.8			
75	G38	890410	6	1.7	-99			
76	G38	900102	1	15	2.2			
77	G38	900131	2	16.8	3.6			
78	G38	900226	3	14.1	4.1			
79	G38	900314	4	6.6	2.8			
80	G38	900328	5	0.5	0.14			
81	G38	900410	6	0	0			
82	G39 CANTON							
83	G39	880104	1	1	-1			
84	G39	880201	2	0	0			
85	G39	880229	3	0	-1			
86	G39	880314	4	0	-1			
87	G39	880328	5	0	0			
88	G39	890130	2	0	-1			
89	G39	890227	3	0	-1			
90	G39	890313	4	4	-99			
91	G39	890327	5	0	-1			
92	G39	890410	6	0	-1			
93	G39	900101	1	2.5	-99			
94	G39	900130	2	9	0.65			
95	G39	900226	3	3	0.56			
96	G39	900312	4	0	-1			
97	G39	900326	5	0	-1			
98	G39	900410	6	0	0			
99								
100	1/	-1	TRACE OR PATCHES					
101		-99	MISSING					
102								
103	2/	NOTES	(used in historical data but are no longer used)					
104		blank	none					
105		E	estimated					
106		A	(average more than 1 site)					
107		I	ice					
108		W	??					
109								
110	INFORMATION FURNISHED BY KEITH EGGLESTON, NORTHEAST REGIONAL							
111	CLIMATE CENTER, CORNELL UNIVERSITY, ITHACA, NEW YORK							
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SNOW SURVEY STATIONS IN US, LAKE ONTARIO BASIN

ATTACHMENT A-4

Basin	Station No.	Station Name	Latitude	Longitude	Elevation
C	1 *	CANADICE AND HEMLOCK LAKES, N.Y.	42.72	77.58	1800
C	2 *	CHURCHVILLE, N.Y.	43.10	77.88	553
C	3 *	GARBUTT, N.Y.	43.02	77.78	600
C	4 *	MT. MORRIS, N.Y.	42.73	77.90	880
C	5 *	RAYMOND, PA.	41.87	77.87	2220
C	6 *	ROCHESTER (AIRPORT), N.Y.	43.12	77.67	543
C	7 *	SCIO (WELLSVILLE), N.Y.	42.17	77.98	1440
C	8 *	WARSAW, N.Y.	42.68	78.20	1715
C	9 *	WHITESVILLE, N.Y.	42.17	77.77	1840
C	10	ANGELICA, N.Y.	42.30	78.02	1420
C	11	AVON, N.Y.	42.92	77.75	545
C	12	DANSVILLE, N.Y.	42.57	77.70	685
C	14	HEMLOCK, N.Y.	42.78	77.62	902
C	16	PAVILLION, N.Y.	42.88	78.03	940
C	17	PORTAGEVILLE, N.Y.	42.57	78.05	1115
C	18	RUSHFORD, N.Y.	42.40	78.27	1560
C	19	WISCOY, N.Y.	42.50	78.07	1140
C	60	BERGEN, N.Y.	43.10	77.93	574
C	61	CANASERAGA, N.Y.	42.47	77.77	1270
C	62	DANSVILLE, N.Y.	42.55	77.72	650
C	63	HONEOYE, N.Y.	42.83	77.53	805
C	64	MT. MORRIS DAM, N.Y.	42.72	77.90	910
C	65	RUSHFORD LAKE, N.Y.	42.38	78.23	1455
C	66	WELLSVILLE, N.Y.	42.10	77.93	1505
C	67	WYOMING, N.Y.	42.82	78.10	975
D	1 *	BALDWINSVILLE (LOCK 24), N.Y.	43.15	76.33	379
D	2	DRESSERVILLE, N.Y. 1NW	42.72	76.35	1160
D	3 *	CAYUGA (LOCK 1), N.Y.	42.95	76.73	385
D	4 *	CLYDE (LOCK 26), N.Y.	43.07	76.83	392
D	5	DRYDEN, N.Y.	42.47	76.32	1700
D	6	ITALY, N.Y.	42.63	77.28	1020
D	7	NORTH LANSING, N.Y.	42.62	76.53	870
D	8	MACDOUGALL, N.Y.	42.82	76.85	675
D	9 *	MACEDON (LOCK 30), N.Y.	43.07	77.30	466
D	10 *	MAYS POINT (LOCK 25), N.Y.	43.00	76.77	380
D	11	MECKLENBURG, N.Y.	42.43	76.75	1430
D	12 *	NEWARK (LOCK 28-B), N.Y.	43.05	77.10	434
D	13	PHELPS, N.Y.	42.93	77.10	640
D	14	ELBRIDGE, N.Y.	43.03	76.45	540
D	15	SECOND MILO, N.Y.	42.62	77.00	1050
D	16	SHELDRAKE, N.Y.	42.68	76.72	400
D	17	SHERWOOD, N.Y.	42.77	76.60	1090
D	18 *	SYRACUSE (AIRPORT), N.Y.	43.12	76.12	419
D	19	SYRACUSE, N.Y. S	42.93	76.17	420
D	20	SYRACUSE, N.Y. SE	42.98	76.13	720
D	21	GLEN HAVEN ROAD, N.Y.	42.77	76.27	875
D	22	HIMROD, N.Y.	42.57	76.97	1120
D	23	LOCKE, N.Y.	42.65	76.45	900
D	24	MANDANA, N.Y.	42.85	76.38	1080
D	25	MARIETTA, N.Y.	42.90	76.32	810
D	26	MARTISCO, N.Y.	43.02	76.33	430
D	27	NEW HOPE, N.Y.	42.80	76.35	1500
D	28	OTISCO VALLEY, N.Y.	42.80	76.22	880
D	29	RESERVATION, N.Y.	42.93	76.17	485
D	30	RICE GROVE, N.Y.	42.85	76.25	800
D	31	SCHOOL NO 10, N.Y.	42.80	76.38	1100
D	32	SKANEATELES, N.Y. GC	42.93	76.43	920
D	33	SPAFFORD, N.Y.	42.80	76.27	1720
D	34	TRUMANSBURG, N.Y.	42.53	76.63	935
D	35	WATERLOO, N.Y. (LK CS-4)	42.90	76.85	450
D	36	EAST BLOOMFIELD, N.Y.	42.90	77.43	965
D	37	ITHACA, N.Y.	42.45	76.45	960
D	38	AURORA, N.Y.	42.73	76.65	830
D	39	VICTOR	42.98	72.67	EST 500
D	55	FULTON (LK3)	MSG	NSG	MSG
E	1	BARNES CORNERS, N.Y.	43.80	75.83	1390
E	2 *	BLOSSVALE, N.Y.	43.30	75.63	430
E	3 *	CAMDEN 2.4 N (WOODS), N.Y.	43.38	75.73	745

SNOW SURVEY STATIONS IN US, LAKE ONTARIO BASIN

E	4 *	CAMDEN, N.Y. (FIELDS AND WOODS)	43.40	75.83	600
E	5 *	CAMDEN 6.1NW, N.Y. (WOODS)	43.40	75.83	600
E	6	CASTOR HILL, N.Y	43.63	75.87	1350
E	7 *	E. BRANCH, N.Y.	43.62	75.77	1300
E	8 *	FISH CREEK CLUB, N.Y.	43.55	75.57	1660
E	9 *	FLORENCE, N.Y.	43.43	75.75	880
E	10 *	GAYVILLE, N.Y. (FIELDS - WOODS)	43.28	76.00	470
E	11 *	GAYVILLE, N.Y. (WOODS)	43.28	76.00	470
E	12 *	GREENBORO, N.Y.	43.63	75.88	1290
E	13	HAPPY VALLEY, N.Y. GMA	43.47	76.00	645
E	14 *	JAMISONS CORNERS, N.Y.	43.37	75.87	695
E	15 *	MALLORY, N.Y. (FIELDS AND WOODS)	43.32	76.12	440
E	16 *	MALLORY, N.Y. (WOODS)	43.32	76.12	440
E	17 *	MCCONNELLSVILLE, N.Y.	43.27	75.70	500
E	18	MEXICO, N.Y	43.45	76.23	470
E	19 *	MUNNSVILLE, N.Y.	42.97	75.58	720
E	20 *	NELSON, N.Y.	42.92	75.82	1620
E	21 *	NEW WOODSTOCK, (2.4N) N.Y.	42.88	75.83	1440
E	23 *	N. CONSTANTIA, NY	43.33	76.00	550
E	24 *	NORTH OSCEOLA, N.Y.	43.58	75.75	1525
E	25 *	OSCEOLA, EAST, N.Y.	43.50	75.67	1340
E	26 *	PANTHER LAKE, N.Y.	43.32	75.90	630
E	27 *	PETERBORO, N.Y	42.98	75.73	1300
E	28 *	PLEASANT VALLEY ROAD, NY	42.95	75.72	1340
E	29 *	POMPEY, N.Y	42.90	76.02	1680
E	30 *	PRATTS HOLLOW, NY	42.92	75.58	1220
E	31	REDFIELD, N.Y.	43.53	75.80	940
E	32 *	HIGHMARKET, NY	43.60	75.53	1820
E	33 *	SANDY POND, N.Y.	43.63	76.18	260
E	34 *	STILLWATER DAM, NY	43.55	75.92	970
E	36 *	TABERG,(1.5W) N.Y. (WOODS)	43.32	75.63	710
E	37 *	TABERG, (3NW) N.Y. (FIELDS-WOODS)	43.33	75.65	820
E	38 *	TABERG (3NW), N.Y (WOODS)	43.33	75.65	820
E	39 *	THOMPSONS CORNERS, NY (FIELDS)	43.38	75.70	900
E	40 *	WEST MONROE, NY	43.28	76.07	420
E	41 *	WILLIAMSTOWN, (1.8S) NY(FL-WD)	43.40	75.88	600
E	42 *	WILLIAMSTOWN (1S), N.Y (WOODS)	43.40	75.88	600
E	45 *	BREWERTON (LOCK 23), NY	43.23	76.20	372
F	1	ATWELL, NY	43.52	74.93	1820
F	2	NEW BREMAN, NY	43.83	75.38	820
F	4 *	BIG MOOSE, NY	43.82	74.87	1880
F	5 *	BOONVILLE (JACKSON HILL), NY	43.43	75.35	1600
F	6 *	BOONVILLE, (1E) NY	43.47	75.30	1150
F	7	BRANTINGHAM, NY	43.68	75.28	1250
F	8	SEARS POND, NY	43.77	75.63	1700
F	10 *	COPENHAGEN, NY	43.87	75.68	1220
F	11	CROGHAN, NY	44.03	75.35	1000
F	12 *	EIGHTH LAKE, NY	43.77	74.72	1810
F	13 *	FORESTPORT, NY	43.45	75.07	1480
F	14 *	FORESTPORT STATION, NY	43.43	75.18	1180
F	16	HAWKINSVILLE, NY 2E	43.50	75.23	1180
F	19	LOWVILLE, NY	43.78	75.48	850
F	20 *	MCKEEVER, NY	43.62	75.10	1580
F	21 *	NORTH LAKE, NY	43.52	74.95	1820
F	22 *	NUMBER FOUR, NY	43.87	75.18	1580
F	23 *	OLD FORGE, NY	43.70	74.93	1810
F	24	PORTERS CORNERS, NY	43.57	75.25	1280
F	26 *	SEARS POND, NY	43.73	75.72	1765
F	27 *	STILLWATER RESERVOIR, NY	43.90	75.05	1700
F	30	TURIN, NY	43.62	75.42	1300
F	31 *	WHITE LAKE (PURGATORY CAMP), NY	43.57	75.13	1550
G	1	BARNUM POND, NY	44.45	74.25	1660
G	2 *	BLUE MT. LAKE, NY	43.87	74.43	2220
G	3	BAY POND, NY. *24	44.45	74.42	1620
G	4	SABATTIS, NY	44.10	74.67	1760
G	5	BUCK POND, NY	43.98	75.07	1780
G	6 *	CARRY FALLS, NY.	42.43	74.75	1386
G	7 *	CHASM FALLS, NY	44.75	74.22	1050
G	8 *	CHATEAUGAY, NY	44.92	74.08	1050
G	9	CHATEAUGAY, NY	44.90	74.08	1180

SNOW SURVEY STATIONS IN US, LAKE ONTARIO BASIN

G	11 *	CONIFER, N.Y.	44.22	74.62	1600
G	12	DICKINSON, N.Y	44.75	74.55	1380
G	13 *	CRANBERRY LAKE, N.Y.	44.22	74.85	1500
G	16 *	GALE, N.Y.	44.27	74.63	1700
G	17 *	HARRISVILLE, N.Y.	44.18	75.35	760
G	18 *	HORSESHOE LAKE, N.Y.	44.15	74.60	1800
G	19 *	LITTLE TUPPER LAKE, N.Y	44.07	74.63	1720
G	20 *	LONG LAKE, N.Y.	43.98	74.45	1760
G	21	LAKE TITUS, N.Y.	44.72	74.28	1563
G	22	MCDONALD POND, N.Y. #25	44.40	74.52	1580
G	23	UPPER & LOWER LAKES, N.Y	44.60	75.22	300
G	24	UPPER ST. REGIS, N.Y.	44.40	74.25	1630
G	25	OWLS HEAD, N.Y.	44.70	74.17	1520
G	26	PANTHER MTN, N.Y.	44.23	74.37	1645
G	27	N BANGOR, N.Y	44.80	74.43	640
G	28 *	PYRITES, N.Y.	44.53	75.18	400
G	29 *	RAQUETTE LAKE, N.Y.	44.23	74.75	1560
G	30	STUDLEY HILL, N.Y.	44.67	74.22	1600
G	31	SANTA CLARA, N.Y.	44.63	74.42	1600
G	32 *	SEVEY, N.Y	44.30	74.72	1540
G	33	S. COLTON, N.Y.	44.43	74.67	1400
G	34 *	STAR LAKE, N.Y	44.17	75.05	1500
G	35	GOODNOW MTN, N.Y	44.62	74.40	1700
G	36 *	TUPPER LAKE, N.Y.	44.12	74.55	1600
G	37	TUPPER LAKE-KILDARE, N.Y.	44.25	74.48	1560
G	38 *	WANAKENA (8-SITE AVG.), N.Y	44.15	74.92	1510
G	39	CANTON	44.57	75.12	EST 400

from Keith Eggleson, Northeast Climate Center, Cornell University

* Classified as long-term station. Records available from 1968 to 1987

Hydrometeorological Data Collection Design and Analysis for the Lake Ontario Drainage Basin

FINAL REPORT - PHASE I
MAY 24, 1991

ATTACHMENT B

CANADIAN DATA BASE

CLIMATE RECORDS

Daily Precipitation Records

Records of monthly precipitation for all precipitation stations with long length of record in the Canadian drainage area have been furnished by Mike Webb (AES), Downsview, Ontario. A listing similar to the one for the U. S. climate stations is being prepared for the precipitation stations in the Lake Ontario drainage in Canada. No records of daily precipitation at Canadian stations have been requested or received.

Basically there are two type of stations in Canada that measures precipitation. One is the ordinary climatological station, at which the water equivalent of snowfall (the amount of precipitation as snow) is obtained by simply dividing the depth of freshly fallen snow by 10 (referred to as the 1 in 10 rule). The other type of station is a synoptic station. At synoptic stations the MSC Nipher snow gage, equipped with a solid wind shield, is used for measuring snowfall. At both stations, the official gage until the 1970-'s for measuring rainfall was the MSC standard copper gage. This is a round gage with a diameter of 3.568 inches, as area of 10 square inches, and installed with the gage orifice 12 inches above the ground.

During the 1970's the standard gage was changed to the Type-B rain gauge (Large Capacity). The Type-B gauge is 36 cm high, has is mounted with the orifice 40 cm above the ground surface. The gauge has a collecting funnel and outer container made of high strength plastic which minimizes adhesion of rain water on the gauge surface, and a clear plastic inner container, graduated for direct reading to the nearest 0.,2 mm. The total capacity of the gauge is over 250 mm, more than double that of the copper gage used previously.

The monthly precipitation values have been processed and placed in tabular form for each long-record station with annual, Oct-Apr and May-Sep totals and 30-yr average values (similar to the monthly form for the US stations). Missing records for stations with long records during the period 1960 to 1990 have been estimated from nearby stations.

Station history information on changes in location of stations are documented in the publication *Climatological Station Catalogue, Ontario.* A computer diskette of this publication has been furnished by Mike Webb (AES).

Hourly Precipitation

Some Canadian climate stations are equipped with recording rain gages (mostly tipping bucket gages). However, only one precipitation amount is official for a location in Canada. Daily records of rainfall from tipping bucket gages are corrected to the rainfall measurement of the standard rain gage. Unless records of hourly and daily amounts of precipitation at hourly stations are required, records from Canadian hourly stations will not be obtained. In the United States, different amount of precipitation for the same day at the same station may be published (one from a recording station and one from a non-recording gage).

Temperature Records

Mean monthly temperature values for a large number of stations have been furnished by AES. No daily values of temperature have been requested at this time.

Wind

Average monthly wind speed records for periods up to 1988 have been furnished by AES for six synoptic stations. Records of daily winds for recent years for the synoptic stations in Canada have been furnished by Tim Hunter (GLERL), Ann Arbor, Michigan.

SNOW SURVEYS

Snow Surveys (Ground)

Historical snow survey records for 73 stations have been furnished by Peter Gryniewski, Ministry of Natural Resources, Toronto, Ontario. Records for an additional 15 stations in the Trent-Severn waterway have been furnished by Bruce Kitchen, Environment Canada, Park Service, Peterborough, Ontario. The earliest of these records began in 1957. The first and last pages of the tabular form of these records for the Lake Ontario drainage basin are shown in **Attachment B-1**.

Information as to location of each snow survey (elevation, latitude, longitude, and length of record) has been prepared and is shown in **Attachment B-2**. Diagrams of the area surrounding some of the snow surveys have also been received. These diagrams include detailed information as to the number of points in a survey and the relative location of the survey line to vegetative cover and terrain features and information on changes in snow survey locations.

Snow Surveys (Airborne Gamma)

No airborne snow survey records are currently available for the Canadian portion of the Lake Ontario Basin. Locations for a new set of surveys in Canada have been selected by the NWS. Airborne gamma radiation surveys were conducted by Robert Grasty, Canadian Geological Survey in the early 1970s using airborne equipment that is now not available.

CANADA SNOW COURSE DATA, LAKE ONTARIO BASIN

ATTACHMENT B-1

ST NO	YR	MO	DY	DP CM	WE CM	CR	SOL	MO	DY	DP CM	WE CM	CR	SOL	MO	DY	DP CM	WE CM	CR	SOL	MO	DY	DP CM	WE CM	CR	SOL	MO	DY	DP CM	WE CM	CR	SOL
ST15	55	3	1	6	5.2																										
ST15	56	2	28	43	16.0																										
2301	57	2	19	69	18			2	25	42	18			3	11	-11	-11														
ST15	57	2	27	11	3.8																										
ST15	58			-99	-99																										
2301	59	1	5	33	9	C	F	1	26	86	26	C	F	2	16	103	37	C	F	2	9	89	26	C	F	3	2	131	51	C	F
2301	59	3	23	52	15	C	F																								
2701	59	3	20	188	63																										
2702	59	3	20	182	59																										
2703	59	3	17	156	66			3	10	174	65			3	20	141	58			3	23	141	55								
ST15	59	2	25	66	11.4																										
2301	60	12	14	47	10	C	W	1	4	67	21	C	F	1	18	72	39	C	F	2	1	122	92	A	F	2	29	135	93	C	F
2301	60	3	14	145	89	B	F	3	28	113	54	A	F		0	0	0				0	0	0								
2701	60	2	3	204	61	C	F	2	17	192	57	C	F	3	1	259	73	C	F	3	15	239	81	C	F						
2702	60	2	3	170	49	C	F	2	17	165	54	C	F	2	29	213	65	C	F	3	15	182	59	C	F						
2703	60	2	3	161	52	C	F	2	17	139	44	C	F	2	29	193	57	C	F	3	16	190	63	C	F						
2704	60	2	3	180	54	C	F	2	17	183	58	C	F	2	29	261	73	C	F	3	16	252	82	C	F						
ST15	60	2	25	38	9.9																										
2301	61	2	17	51	31	B	F	3	1	0	0																				
2701	61	1	1	85	9	A	F	1	16	52	8	C	F	2	1	67	12	C	F	2	14	63	14	A	F	3	1	44	12	B	F
2701	61	3	15	48	15	A	W	3	31	0	0																				
2702	61	1	1	77	9	A	F	1	16	51	9	C	F	2	1	69	9	C	F	2	14	61	12	A	F	3	1	45	12	B	F
2702	61	3	15	50	16	A	W	3	31	0	0																				
2703	61	1	3	113	21	A	F	1	16	72	19	C	F	2	1	88	19	C	F	2	14	80	27	A	F	3	1	38	13	A	F
2703	61	3	17	37	12	C	F	3	31	0	0				0	0	0				0	0	0								
2704	61	1	3	117	23	A	F	1	17	88	20	C	F	2	1	95	21	C	F	2	15	95	23	C	F	3	1	61	22	A	F
2704	61	3	17	61	18	C	F	3	31	0	0																				
ST11	61	2	22	9	1.0																										
ST15	61	2	21	32	5.3																										
2301	62	1	15	79	11	A	F	1	29	73	19	A	F	2	12	55	12	B	F	2	26	170	50	B	F	3	14	129	59	C	F
2701	62	1	15	84	16	C	F	2	1	100	15	C	F	2	15	126	29	C	F	3	1	150	35	C	F	3	15	145	38	C	F
2702	62	1	15	67	11	C	F	2	1	93	23	C	F	2	15	121	25	C	F	3	1	148	41	C	F	3	15	147	48	C	F
2703	62	1	15	74	13	B	F	2	1	103	16	C	F	2	15	143	29	C	F	3	1	138	37	C	F	3	15	134	45	A	F
2704	62	1	16	77	11	C	F	2	2	106	18	C	F	2	16	142	24	C	F	3	2	168	39	C	F	3	15	152	50	A	F
ST11	62	2	23	40	10.2																										
ST15	62	2	23	66	15.5																										
1203	63	1	15	55	12	B	F	2	1	83	19	C	F	2	15	101	21	C	F	3	4	90	24	C	F	3	15	93	30	C	F
2301	63	1	21	59	16	B	F	1	8	31	7	B	F	2	11	69	21	C	F	3	4	66	16	C	F		0	0	0		
ST11	63	2	19	32	6.6																										
ST15	63	2	20	40	8.6																										
1203	64	1	3	119	17	A	W	1	15	73	17	C	F	1	31	46	14	C	F	2	14	83	20	C	F	3	2	72	22	A	F
1203	64	3	16	0	0																										
2301	64	1	3	122	22	B	D	1	21	51	18	C	F	2	23	48	11	C	F	3	15	0	0								
2701	64	1	4	127	24	B	F	1	15	94	26	C	F	1	31	-11	-11			2	14	115	29	A	F	2	28	87	34	B	F
2701	64	3	15	0	0																										
2702	64	1	4	110	26	B	F	1	15	77	30	C	F	1	31	-11	-11			2	14	82	21	A	F	2	28	80	34	B	F
2702	64	3	15	0	0																										
2703	64	1	4	87	22	B	F	1	15	56	20	C	F	1	31	-11	-11			2	14	65	20	A	F	2	28	48	23	B	F
2703	64	3	15	0	0																										
2704	64	1	6	109	24	B	F	1	15	81	24	C	F	1	31	-11	-11			2	14	115	30	A	F	2	28	100	40	B	F
2704	64	3	15	0	0																										
ST11	64	2	19	12	4.6																										
ST15	64	2	20	29	9.1																										

CANADA SNOW COURSE DATA, LAKE ONTARIO BASIN

ST-9	90	1.2	2	25	4.5 B	F	1 16	33.8	6.6 A	F	1 30	31.1	7.4 A	F	2 6	32.6	6.5 A	F	2 13	28.6	7.4 E	F										
			2 20	30.2	7.8 B	F	2 27	32.7	7.2 B	F	3 6	29.2	8.2 D	F	3 13	.21	6.8 A	UW	3 20	10	0.2 A	UW										
ST10	90	1.2	2	11	1.9 B	F	1 16	11.8	2.2 A	F	1 30	7.6	1 A	F	2 6	9.3	1.4 A	F	2 13	1.8	0.4 E	F										
			2 20	11.2	1.5 B	F	2 27	13.8	1.4 B	F	3 6	7.6	1.6 D	F	3 13	0	0		3 20	0	0											
ST11	90	1.2	2	13.4	1.8 A	F	1 16	13.2	3.1 A	F	1 30	11.1	3.2 A	F	2 6	9.3	1.4 A	F	2 13	1.6	0.9 E	F										
			2 20	11.3	2 B	F	2 27	12.8	3.3 B	F	3 6	10.6	4.4 E	F	3 13	0	0		3 20	0	0											
ST12	90	1.2	2	14.8	2.2 A	F	1 16	15.5	3.7 A	F	1 30	12.1	3.1 A	F	2 6	12.8	3.6 A	F	2 13	4	1.3 E	F										
			2 20	15.6	3.2 B	F	2 27	16.8	3.2 A	F	3 6	14	4 E	F	3 13	0	0		3 20	0	0											
ST13	90	1.2	2	32.1	5.7 B	UW	1 16	38.1	8.7 A	F	1 30	35.1	8.9 E	F	2 6	39.4	9.5 E	F	2 13	22.7	6.4 E	F										
			2 20	42.4	10.3 B	F	2 27	40.6	9.9 A	F	3 6	27.9	6.5 E	F	3 13	22.2	8.1 A	F	3 20	7.6	1 E	F										
ST14	90	1.2	2	18.9	2.2 A	F	1 16	16.9	4.1 B	F	1 30	10	2.3 E	F	2 6	10.9	2.4 E	F	2 13	0	0											
			2 20	10.8	1.3 B	F	2 27	17.7	3.7 A	F	3 6	6.1	1.2 C	F	3 13	0	0		3 20	0	0											
ST15	90	1.2	2	21.8	4 B	F	1 16	23	4.3 B	F	1 30	14.6	5.3 E	F	2 6	16.1	5.3 E	F	2 13	7.1	2 B	F										
			2 20	18.5	2.6 B	F	2 27	21	4.8 A	F	3 6	14.3	3.0 C	F	3 13	0	0		3 20	0	0											

-11 TRACE -90 PATCHES -99 MISSING

CRUST CONDITIONS CODES

A NO CRUST
B LIGHT CRUST
C CRUST STRONG ENOUGH TO HOLD A PERSON ON SNOWSHOES
D CRUST STRONG ENOUGH TO HOLD A PERSON
VAR VARYING

SOIL CONDITION CODES

F FROZEN SOIL
UD SOIL IS UNFROZEN AND DRY
UW SOIL IS UNFROZEN AND WET
THIS CODE IS FOLLOW BY A ZERO (0) TO INDICATE THAT RESULTS ARE IN IMPERIAL UNITS (i.e. 1/10") OR BY A ONE (1) TO INDICATE THAT RESULTS ARE IN METERIC (i.e. CM FOR SNOW DEPTH AND MM FOR WATER EQUIVALENT).

FROM
PETER GRYNEIWSKI - MINISTRY OF NATURAL RESOURCES ONTARIO, CANADA

FROM
BRUCE KITCHEN - ENVIRONMENT CANADA PARKS SER., PETERBOUROUGH, ONTARIO HYDEX MAY 91

CANADIAN SNOW COURSES, LAKE ONTARIO BASIN

ATTACHMENT B-2

STA #	WATERSHED	SNOW COURSE NAME	BEG YR	YRS 91	EL(m)	LAT	MIN	LONG	MIN
701	BRONTE CR WATERSHED	MORRISTON	73	14	305	43	27	80	5
702	BRONTE CR WATERSHED	MOUNT NEMO	73	14	282	43	25	79	53
801	OAKVILLE CR WATERSHED	KELSO	73	14	305	43	31	79	59
901	CATARAQUI R WATERSHED	BATTERSEA	75	13	137	44	25	76	24
1001	BUELL CR WATERSHED	BROCKVILLE	71	17	107	44	38	75	44
1101	GANANOQUE R WATERSHED	DELTA	71	17	100	44	36	76	7
1102	GANANOQUE R WATERSHED	GANANOQUE	81	10	106	44	24	76	15
1103	GANANOQUE R WATERSHED	ATHENS	81	10	129	44	38	75	57
1104	GANANOQUE R WATERSHED	OUTLET	81	9	107	44	30	76	4
1105	GANANOQUE R WATERSHED	BLACK RAPIDS	81	9	114	44	31	76	6
1106	MILLHAVEN CR WATERSHED	GOULD LAKE	90	1	150	44	28	76	36
1107	LITTLE CATARAQUI WATESHED	KINGSTON	90	1	120	44	17	76	30
1201	CREDIT R WATERSHED	BELFOUNTAIN	75	14	366	43	48	80	1
1202	CREDIT R WATERSHED	MONORA (ORANGEVILLE)	71	2	427	43	56	80	6
1203	CREDIT R WATERSHED	TERRA COTTA	63	26	343	43	43	79	57
1204	CREDIT R WATERSHED	HILLSBURGH	73	16	480	43	48	80	10
1205	CREDIT R WATERSHED	MEADOWVALE	85	6	166	43	38	79	44
1301	CROWE R WATERSHED	CARDIFF	73	13	357	44	59	77	58
1302	CROWE R WATERSHED	COE HILL	73	13	326	44	51	77	53
1303	CROWE R WATERSHED	CORDOVA	73	12	202	44	30	77	48
2301	HUMBER R WATERSHED	ALBION HILLS	57	24	268	43	56	79	50
2302	HUMBER R WATERSHED	COLD CR	79	11	268	43	55	79	42
2303	HUMBER R WATERSHED	CLAIREVILLE	79	11	168	43	45	79	40
2304	HUMBER R WATERSHED	BOYD	78	12	165	43	49	79	35
2305	DUFFIN CR WATERSHED	CLAREMONT	78	11	180	43	50	79	5
2306	DUFFIN CR WATERSHED	STOUFFVILLE	79	11	268	43	58	79	14
2307	ETOBICOKE CR WATERSHED	HEART LAKE	79	11	253	43	45	79	48
2308	ROUGE R WATERSHED	BRUCE'S MILL	79	11	256	43	57	79	21
2401	SPENCER CR WATERSHED	CHRISTIES CORNERS	73	16	241	43	17	80	2
2402	SPENCER CR WATERSHED	MOUNT ALBION	77	13	183	43	12	79	50
2403	SPENCER CR WATERSHED	VALENS	70	21	274	43	23	80	8
2404	SPENCER CR WATERSHED	DUNDAS VALLEY	71	6	145	43	15	80	1
2701	MOIRA R WATERSHED	MADOC (O'HARA)	59	26	198	44	31	77	31
2702	MOIRA R WATERSHED	ACTINOLITE (PRICES)	59	25	167	44	33	77	20
2703	MOIRA R WATERSHED	PLAINFIELD (HOSKIN'S)	59	26	107	44	17	77	21
2704	MOIRA R WATERSHED	STIRLING (SPRACKETT'S)	60	26	190	44	16	77	30
2705	MOIRA R WATERSHED	MILLBRIDGE	79	26	305	44	43	77	35
2706	MOIRA R WATERSHED	HAWKINS BAY	84	7	168	44	31	77	19
2707	MOIRA R WATERSHED	LIME LAKE	84	7	160	44	23	77	10
2901	NAPANEE R WATERSHED	SECOND DEPOT LAKE	73	16	168	44	33	76	24
2902	NAPANEE R WATERSHED	FOURTH DEPOT LAKE	75	14	168	44	36	76	47
3101	OTONABEE R WATERSHED	SQUIRREL CR	72	15	190	44	11	78	20
3201	INDIAN R WATERSHED	WARSAW	72	16	235	44	27	78	5
3801	TRENT R WATERSHED	CAMPBELLFORD (SEYMOUR)	76	14	137	44	17	77	48
3802	TRENT R WATERSHED	HUNTINGDON (SILLS)	76	14	143	44	21	77	27
3803	TRENT R WATERSHED	ORLAND (LOOMIS)	76	14	137	44	8	77	49
3901	BUTLER CR WATERSHED	BRIGHTON (PROCTOR)	76	14	151	44	3	77	45
4001	WELLAND R WATERSHED	MOUNT HOPE	73	16	216	43	8	79	56
4002	WELLAND R WATERSHED	SOUTHCOTE	73	12	240	43	11	79	57
4003	WELLAND R WATERSHED	WAINFLEET (WINGER)	78	10	177	42	56	79	27
4004	WELLAND R WATERSHED	BINBROOK	84	6	213	43	7	79	51
4005	WELLAND R WATERSHED	CHIPPAWA	84	6	180	42	59	79	31
4006	BLACK CREEK	STEVENSVILLE	84	0	180	42	56	79	4
4007	FOUR MILE CREEK	VIRGIL	90	0	96	43	12	79	7
4101	BLACK R (L ONTARIO DRAINAGE)	BLACK RIVER	85	5	98	43	56	77	6
4102	DEMORESTVILLE CREEK WATER	DEMORESTVILLE CREEK	85	5	107	44	6	77	12
4103	CONSECON CREEK WATERSHED	CONSECON CREEK	85	5	110	44	3	77	18
4104	LANE CREEK WATERSHED	LANE CREEK	85	5	91	43	53	77	19
4105	BLOOMFIELD	BLOOMFIELD CREEK	85	4	96	44	0	77	13
4106	MARSH CREEK WATERSHED	MARSH CREEK	85	5	116	44	0	77	8
4601	COBOURG R WATERSHED	HARWOOD	79	11	297	44	6	78	10
4602	COBOURG R WATERSHED	CAMBORNE	80	10	229	44	3	78	11
4603	GRAHAM CR WATERSHED	STARKVILLE	80	10	168	43	59	78	31
4701	LYNDE CR WATERSHED	ASHBURN	79	10	267	44	0	79	1
4801	OSHAWA CR WATERSHED	MOUNT CARMEL	79	9	273	44	1	78	53
4802	OSHAWA CR WATERSHED	RAGLAN PURPLE WOODS	82	9	305	44	2	78	56
4901	BOWMANVILLE CR WATERSHED	STEPHEN'S GULCH 1 CON III	79	9	144	43	57	78	42
4902	BOWMANVILLE CR WATERSHED	STEPHEN'S GULCH 2 CON IV	79	10	146	43	58	78	41

CANADIAN SNOW COURSES, LAKE ONTARIO BASIN

4903	BOWMANVILLE CR WATERSHED	LONG SAULT	81	10	312	44	3	78	46
6801	BALSAM LAKE WATERSHED	COBOCONK	87	4	265	44	38	78	50
6802	STURGEON LAKE WATERSHED	CAMERON	87	4	250	44	24	78	46
6803	PIGEON R (KAWARTHA L.)	PONTYPOLL	91	4	275	44	8	78	41
6804	MARIPOSA BROOK WATERSHED	WOODVILLE	91	0	264	44	23	79	0

FROM PETER GRYNIEWSKI, MINISTRY OF NATURAL RESOURCES, ONTARIO

ST-1	EAGLE LAKE	TRENT-SEVERN WATERWAY	77	15	404	45	8	78	29
ST-2	LITTLE BOB LAKE	TRENT-SEVERN WATERWAY	77	15	305	44	54	78	48
SY-3	FURNACE FALLS	TRENT-SEVERN WATERWAY	77	15	305	44	50	78	34
ST-4	BEAR LAKE	TRENT-SEVERN WATERWAY	77	15	380	44	58	78	24
ST-5	CARNARVON	TRENT-SEVERN WATERWAY	77	15	305	45	0	78	53
ST-6	BALSAM LAKE PROV. PARK	TRENT-SEVERN WATERWAY	77	15	275	44	38	78	52
ST-7	SIBBALD POINT PROV. PARK	TRENT-SEVERN WATERWAY	79	13	225	44	19	79	19
ST-8	SERPENT MOUNDS PROV. PARK	TRENT-SEVERN WATERWAY	77	15	190	44	13	78	10
ST-9	EEL'S LAKE	TRENT-SEVERN WATERWAY	77	15	365	44	53	78	8
ST10	STONY LAKE	TRENT-SEVERN WATERWAY	77	15	240	44	35	78	5
ST11	LITTLE BRITAIN	TRENT-SEVERN WATERWAY	79	13	265	44	17	78	52
ST12	EMILY PROV PARK	TRENT-SEVERN WATERWAY	77	15	245	44	20	78	30
ST13	COOPER'S FALLS	TRENT-SEVERN WATERWAY	77	15	245	44	48	79	12
ST14	SCANLON CREEK CONSV AREA	TRENT-SEVERN WATERWAY	61	32	240	44	9	79	34
ST15	GILCHRIST	TRENT-SEVERN WATERWAY	46	46	279	44	26	79	36

FROM BRUCE KITCHEN, ENVIRONMENT CANADA PARKS SER., PETERBOUROUGH, ONTARIO

HYDEX MAY 91

Hydrometeorological Data Collection Design and Analysis for the Lake Ontario Drainage Basin

FINAL REPORT - PHASE I
MAY 24, 1991

ATTACHMENT C

ADJUSTMENT TECHNIQUES FOR PRECIPITATION RECORDS

NEED FOR A KNOWLEDGE OF ACTUAL PRECIPITATION

Hydrologists have long recognized that deficiencies exist in precipitation measurements, especially when it occurs in the form of snow. Errors in measurement of precipitation account for a large portion of the inaccuracies in precipitation-runoff and in hydrological modeling of runoff or lake inflow . A considerable effort has been devoted by scientists around the world on the development of techniques and instrumentation for improvement in the measurement of precipitation. The use of conceptual modeling has greatly increased the need for improved knowledge of the amount and distribution of the actual precipitation, rather than an index to the amount. Beside the need for improved knowledge of the actual amount of precipitation for hydrological modeling, this knowledge is also needed for accurate assessment of the total deposition of acid rain and other environmental and hydrometeorological modeling of the atmosphere and lithosphere.

ACCURACY OF PRECIPITATION SENSORS

Many investigators, Kurtyka (1), Israelsen (2), and Larson (3) have presented reviews of the various instruments and techniques developed over the past 100 years to improve the measurement of precipitation. The World Meteorological Organization (WMO) published a comprehensive review of the many problems associated with precipitation measurement in the WMO/IHD Report No 16, *The Precipitation Measurement Paradox -- The Instrument Accuracy Problem*, by Rodda (4). All of the above reports agree that there is a deficiency in the measurement of precipitation which is normally much greater for snowfall than for rainfall and that the deficiency in the catch is primarily the results of wind action and turbulence around and over the orifice of the gaging instrument. Other sources of error in precipitation measurement are the result of loss due to wetting of the gage and, especially for areas where most precipitation is light and in the form of snow, the loss by not accounting for precipitation during periods when a trace (< 0.005 inch in the U.S. and < 0.2 mm in Canada) is recorded.

Many different types of precipitation gages and devices to protect precipitation gages from the adverse effects of wind have been developed. The most common has been the development of wind shields to reduce the adverse effects of wind movement at the gage orifice. The use of windshields, for gage sites where wind is a factor, does result in a gage catch which is normally greater than that without the use of a windshield, but which is still less than the true amount of precipitation.

EXPOSURE OF PRECIPITATION GAGES

Bogdanova (5) showed that in a well protected site, such as in a small opening in a large coniferous type forest, the catch in a precipitation gage does provide a fair indication of the average snowfall in the surrounding area. Similar research was conducted by this author and other NWS personnel at the Sleepers River Watershed near Dansville, Vermont. In this research, many types of precipitation gages (with and without windshields) were installed in a site in a small forest clearing. The site was protected from wind movement by a wall of black plastic entirely surrounding the site, extending from the ground to near the top of the trees (referred to as the black hole). Analyses of the amount of precipitation measured in the various precipitation gages showed that there were essentially no differences in the measured precipitation (for both snowfall and rain). The precipitation as measured in the precipitation gages related one to one with the water equivalent of the snowfall for the same storm period as measured in the protected site and as estimated from many precipitation and snow survey measurements in the research area. An anemometer installed in the black hole verified that there was no wind movement in the protected site.

The conclusions of this research supported the findings of Bogdanova and others that under no wind conditions all precipitation gages, with and without a windshield, measures the same amount of precipitation and that the measurements reflect the actual precipitation that is received at the ground surface. However, no gage in the real world is so protected from adverse wind effects and catches in almost all gages measure less than actual precipitation, especially for snowfall. The measurement problem is also compounded by the fact that under the same.wind conditions, different gages will measure a different proportion of the actual precipitation.

The results of research by Brown and Peck (6) demonstrated that the exposure of a gage site, or the degree of protection afforded a precipitation gage from adverse wind movement by surrounding objects, is the most important factor relating to the accuracy of a gage in measuring true precipitation. Brown and Peck (6) developed a subjective exposure classification system, based on the degree of protection afforded by nearby objects and by the general terrain near the gage. This system was used in a snowfall measurement project by the NWS to classify precipitation gage sites in the Lake Ontario drainage area during the International Field Year for the Great Lakes (IFYGL) in the early 1970s (7). The Brown and Peck subjective classifications of exposure, in order of protection provided by nearby objects and the general terrain, are:

1. Well-protected. Sheltered in all directions by objects subtending angles of 20° to 30° from the gage orifice with none greater than 45°, and with objects of sufficient breadth to minimize edge effects. As example of a well-protected site is an open area in a large coniferous forest, where the vegetation provides maximum protection the year around. The gage should not be located so that strong winds would be funneled into the area by the surrounding terrain.
2. Protected. Sheltered by the general terrain of the area but not fully protected from wind action on the gage by objects in the vicinity. The unprotected directions should not be in the general direction of the winds associated with precipitation.
3. Fairly well-protected. May or may not be sheltered by the general terrain. Nearby objects provide some protection from winds associated with major storms. The precipitation catch would be reduced during snow storms with strong general winds.
4. Moderately windy. Little protection by the general terrain. Nearby objects do not have the expanse or breadth to afford adequate protection from winds during periods of precipitation.
5. Windy. Little or no protection from nearby objects but the location may have some protection afforded by the general terrain.
6. Very Windy. No protection from the general terrain, or the general terrain is such that the location is subject to stronger winds that found in the area. Little or no protection from nearby objects. Examples would be gages exposed on mountain tops or ridges or at the mouth or head of canyon where strong winds might be funneled to the site. Both "windy" and "very windy" locations have very open exposures. The difference is that a "very windy" location is subject to adverse effects because of the general terrain.
7. Overprotected. One or more objects in the vicinity of the gage extending an angle of more than 45° in the vertical, with that portion of the object or objects extending above 45o having a horizontal angle greater than 10°.

NEED FOR ADJUSTMENT OF PRECIPITATION RECORDS

A report prepared by Walter Wilson (8) published in the Monthly Weather Review presented an excellent case for using precipitation records that are as near as possible to the actual amount of precipitation for hydrological modeling. His report clearly demonstrated that precipitation records from stations having a good exposure, i. e., protected from strong wind movement, had a much higher correlation with streamflow that did records from stations which were poorly exposed, i. e., open to wind movement.

Hydrologists of the National Weather Service (NWS) have used correction factors to adjust precipitation records when using precipitation records for conceptual hydrological modeling. These adjustments, or corrections, usually takes the form of a simple multiplying factor greater than unity to be applied to snowfall measurements. For basins with a major contribution from snowmelt, the National Weather Service River Forecast System (NWSRFS) permits the calculation of a snow correction factor (SCF) for correcting precipitation in the form of snow during the calibration of its snowmelt model to a snowmelt basin. Larson and Peck (9) demonstrated that for bulk input (single precipitation value for the basin) conceptual modeling that include snow-accounting processes provide better simulation results if the wind induced snow precipitation measurement error is reduced through the use of an SCF.

Many users assume that precipitation data collected by, and published by, a national hydrometeorological organization, such as the NWS in the United States and the AES in Canada, are collected using standard criteria. This is not true for equipment in the United States. It is especially not true for exposure of precipitation gages in both countries. Since the most critical factor affecting the accuracy (and deficiency) of precipitation measurement is the wind movement at the height of the orifice of the gage during precipitation occurrence, one may think that the exposure of a gage for measuring precipitation should be a primary consideration for location of a precipitation gage. However, this is not the case. Unless adjustments of precipitation records are made to correct for adverse wind effects and other errors in precipitation measurement, the use of published precipitation values for conceptual hydrological modeling, without proper consideration for measurement errors, will be misleading.

ADJUSTMENT PROCEDURES - UNITED STATES

The US precipitation gage records will be adjusted by procedures developed by Hydex. One adjustment is based on a knowledge of the exposure of the gages to determine the gage catch deficiency as a result of wind action. The daily records of the observers who operate the gages will be used to account for losses due to wetting of the gage and for the loss in catch when a trace amount is reported. A trace of precipitation is considered as zero amount of precipitation in both Canada and the United States. The procedures are based on research work by the World Meteorological Organization WMO, the NWS, scientists in the USSR, scientists of the AES in Canada, and by many other investigators.

Adjustments at Synoptic Stations

Larson and Peck (9) used information from many foreign and U. S. research reports, from research accomplished by the NWS at the Sleepers River Watershed in Danville, Vermont, and from studies conducted by the NWS and the U. of Wyoming near Laramie, Wyoming, to develop generalized curves for adjusting daily precipitation measurements for synoptic weather stations in the eastern United States. Wind sensors at synoptic stations (most are at airports) are generally installed at 20 feet above the ground. To determine the wind at the orifice level of the precipitation gage, the wind values from the wind sensors are reduced to the height of the precipitation gage orifice using the power-law profile,

$$U_{gage} = U_{wind} \left(\frac{Z_{gage}}{Z_{wind}} \right)^{k} \quad , \qquad (1)$$

where U_{gage} is the daily wind movement at the gage height, U_{wind} is the daily wind movement as measured at height of the anemometer, Z_{gage} is the height of the precipitation gage, Z_{wind} is the height of the wind anemometer, and k a power. The value of k is dependent upon the stability of the atmosphere near the ground and on the roughness of the surface. A value of 1/7 for k in equation 1 is suggested in the book *Hydrology for Engineers* (10). A computation of k values at NWS synoptic stations using observed wind values at two levels (mainly 20 feet and 2 feet) indicated a value of 0.3 for k (unpublished report by the Hydrologic Research Laboratory NWS, Silver Spring, MD). Atmospheric conditions are generally most stable during the cold season when snow occurs. Since snowfall is the most important form of precipitation to be adjusted, and to be conservative, a value of 1/5 for k has been used by Hydex in the past. Before finalizing a value for k for the present project, more investigation will be conducted. The difference in estimated gage deficiency from using a 1/5 value compared with using a 1/7 value is small.

Figure C-1 shows curves, adapted from Larson and Peck (9) for obtaining the deficiencies in the daily catch in a precipitation gage based on the average daily wind speed (in mph) for:

a. Rain
b. Snowfall (with a windshield)
c. Snowfall (without a windshield)

The relationship in Figure C-1, and those in Figures C-2 through C-9, were developed during an analysis study for the Environmental Protection Agency (EPA) to provide a consistent and reliable precipitation data set for evaluation of acid rain deposition simulation models (11).

The rain curve in Figure C-1 is used to determine the deficiency in the daily catch due to wind effects when the precipitation is in the form of rain. Synoptic stations in the northeast area of the United States are usually equipped with a shielded recording gage (which is used for the official precipitation measurement) and therefore the middle curve (Snow with windshield) is used for US synoptic stations in the Lake Ontario area when snowfall occurs.

At synoptic stations, the type of precipitation is generally reported each day. For mixed forms of precipitation at synoptic stations, rain and snow or other combinations of frozen precipitation with rain, the average of the deficiencies determined using (a) the rain curve, and (b) the snow with windshield curve, from Figure C-1 is used. Mixed forms of precipitation most often occurs when the daily average air temperature is between 27° F and 32° F.

Adjustments at Climate Stations

Wind measurements are very seldom available at daily climate stations. A few stations that measure pan evaporation normally report wind movement at the height of the evaporation anemometer (about 2 feet) but only during the warmer months of the year. Therefore, some method is needed to determine the wind adjustment factor to adjust daily or monthly precipitation totals from climate stations.

One method would be to estimate the daily or monthly wind movement at the height of the gage orifice from available wind measurements in the area. A research study was conducted by the author (unpublished) using hourly recording wind records from NWS synoptic and from U. S. Forest Service Ephraim Research experiment stations in Utah. Average hourly, daily and monthly wind speed values were correlated for stations located along the western side of the Wasatch mountains that traverse north-south through the central portion of the State. The interesting result of this study was that records of average daily (and monthly) wind speeds were well correlated (r greater than 0.85) for pairs of stations where wind measurements were made in the open, i. e., at airports where the wind measurement is made at open exposures with little or no protection from the wind. This was true for sites on the same side of the mountain range even as far as 175 to 250 miles apart (Salt Lake City to Milford and Salt Lake City to Modena, Utah).

A good correlation was also found between wind movement at the Salt Lake City airport (4,200 feet) and at open sites at the Ephraim Research area high in the mountains (over 9,000 feet). Little or no linear correlation was found between wind records for measuring sites only a few hundred feet apart when one of the sites had an open exposure and the other was located in an area protected by trees and bushes.

The results of the research demonstrated that a measure of wind speed in an open site can be used to estimate the wind speed in other open sites over considerable distances for locations not separated by mountain ranges.

Wind records for the synoptic stations in the Lake Ontario basin were analyzed to determine if these records were correlated on a daily or monthly basis as was observed in Utah. It was found that average wind speeds at Buffalo and at Rochester, New York, correlated well for both daily and monthly periods (r^2 approximately 0.78). Figure C- 2 is a plot for Buffalo and Rochester of average monthly wind speed (for 12 winter months in 1989 and 1990). Figure C-3 is a plot of average wind speed for the two stations for February-March 1989.

Analysis of the correlation between average wind speed at Syracuse with those at Rochester were not as well correlated (r^2 approximately 0.65). This was expected since the Syracuse Airport is more protected from general wind movement by the local terrain and vegetation in the area and the wind sensor is not as open to wind movement as are the wind sensors at Rochester and Buffalo.

Since there is a high correlation for both daily and monthly periods between the average wind speed at Buffalo and Rochester, it is possible to estimate the average daily or monthly wind speed for other precipitation stations installed at open sites around Buffalo and Rochester. Daily adjustment factors may be determine for precipitation station records at open sites using estimated wind speed values and the curves in Figure C-1.

During the initial development of the adjustment techniques for EPA (11), daily precipitation records were adjusted for other synoptic stations at open exposures in the eastern United using Figure C-1 and the daily adjusted values were summed to obtain monthly adjusted values. The monthly adjusted values were compared with observed values to compute monthly adjustment factors. These computed monthly adjustment factors were used to prepare the topmost curve (for windy sites) in Figure C-4 (For Computation of Deficiency in Catch of Rain, U. S. Precipitation gages). No data are available for developing a curve for "very windy" sites for Figures C-4. Very windy sites are generally found on and near higher mountains than exist in the Lake Ontario drainage area.

Adjustment for Other than Windy Sites.

Most climate stations are located at sites that are partially, or in some cases very well protected, from wind movement. The wind movement at such sites is less than occurs at open sites. A means of estimating the daily or monthly wind movement at these less windy site is needed.

The curves for rain measurement for exposures other than windy in Figure C- 4 have been arbitrarily assigned as percentages of the windy curve as follows: moderately windy, 0.75%; fairly-well protected, 0.50%, protected, 0.25: and well-protected 0.0%. No curve is given for the classification Overprotected since these are rarely found (substation network specialists in the US who install gages are instructed to avoid such locations) and the deficiency in catch is not much different in most cases than that for well-protected sites.

Sets of curves for use with snow measurements for gages with and without snowfall, similar to the curves for rain in Figure C-4, are needed. The curves for windy exposures on Figure C-5 (for US gages without windshields) and Figure C-6 (for US gages with windshields) were developed using precipitation and wind measurements from synoptic stations as was done for computation of the windy curve in Figure C-4.

The positioning of curves for the other exposure classifications on Figures C-5 are based on the relative deficiencies found for the different exposure classifications for the same wind speeds as reported in the paper by Brown and Peck (6).

The curves for deficiency in snowfall catch for gages without windshields (Figure C-6) have been adjusted upwards from those in Figure C-5 using on the results of research reported in the literature comparing the deficiencies of catch of snowfall with and without a windshield.

The basic assumption for the use of the curves in Figures C-1, C-4, C-5 and C-6 is that wind measurements at a windy site represents the wind movement in the general area. The wind movement for the open site can be estimated using wind records from nearby windy locations. For less open sites, the wind movement should be proportionally lower, depending upon the amount of protection offered to the precipitation by the vegetative cover and by terrain features.

Adjustment for Cases of Mixed Forms of Precipitation

When the curves for monthly adjustment of precipitation are used the following criteria are used to determine when to use the rain (Figure C-4) or snow curves (Figures C-5 and C-6), or an average of the two deficiencies:

Average Monthly Temperature (T)
Rain $T > 28^{\circ}F$
Snow $T < 24^{\circ}F$
Mixed $24^{\circ}F = T = 28^{\circ}F$

Assignment of Exposure Classification for a Gage Site.

The use of an exposure classification system would not be required if wind speed were measured at each precipitation gage site. However, technicians and scientists can be readily trained to use the system to determine a proper exposure classification for a site. As indicated in the this report, the Brown and Peck (6) exposure classification system was used during the installation and evaluation of gage sites in the Lake Ontario drainage area during the IFYGL studies in 1973 and 1974. It was found that with experience the Substation Network Inspector for New York at that time (Donald L. Quick) came up with essentially the same classification of sites as this author. Subsequently, prior to his retirement, Donald Quick produced many detailed diagrams documenting on the station history forms for precipitation station locations in the State of New York that are excellent for use in defining the exposure of stations in the Lake Ontario area.

Stations history files are available at the Washington NWS offices. Copies of station history forms for all stations listed in Attachment A-1 of Attachment A have been obtained.

Adjustment for Wetting of the Gage and for Traces

It has been the practice of Hydex to correct for trace days at climate and synoptic stations by adding a 0.005 inch to the total precipitation for the month for each day a trace amount is reported. Goodison (12) has shown that a correction for wetting of a gage when the amount of precipitation is measured is required for type MSC Canadian precipitation gage since the liquid is poured from the gage for the observation. For the MSC gage Goodison has proposed a wetting correction of 0.07 mm per observation (or 0.25 mm per day). The new Type-B rain gage has a measurement tube that is transparent and the measurement is made visually. This gage does not require the liquid to be poured from the gage. A wetting correction for the US standard 8-inch raingage is not as important since the liquid is not poured from the gage for rain measurement but measured using a wooden stick.

Goodison has also recommended a correction value of 0.15 mm for each observation a trace is reported (personal communication).

ADJUSTMENT PROCEDURES - CANADA

Adjustment of Daily Measurements for Synoptic Stations

Measurement of precipitation at synoptic stations in Canada is done separately for rain and snowfall. Rain is measured using the Type-B standard gage. A search of the literature did not produce a curve relating gage deficiency with wind movement for the Type-

B gage but measurements are being compared with pit gage rainfall for this purpose. The available information on catch deficiency of rain gages with diameters smaller than 8 inches is not consistent. Huff (13) reported that there were small differences in catch or rain for a three-inch orifice gage and a standard 8-inch gage. Unpublished studies by the NWS, at the Danville, Vermont, Sleepers River Watershed snowmelt study site, indicated that the deficiency for rain catch by a four-inch gage was about half that for an eight-inch gage with 4 to 5 mph wind movement (ground truth pit gage measurements were used in the comparison study). Goodison (private communication) of AES Canada has indicated that the average catch deficiency for rain is on the order of 4 to 5 percent using the MSC standard copper gage. Goodison has reported that preliminary comparison with pit gage measurements indicates that the catch deficiency for the Type-B gage is on the order of 2%.

Based on the evidence available, the gage catch deficiency for the Canadian standard rain gage for this project will be considered to be one-half of the deficiency for an eight-inch rain gage (one-half of the deficiencies determined using Figure C-1).

For measurement of snowfall at synoptic stations in Canada the MSC Nipher snow gage is used. This is equipped with a solid wind shield. Goodison (12) has shown that for light winds (up to 5.5 mps), the Nipher gage measurements are within 10 percent of estimated true snowfall, with the catch being slightly above true snowfall for wind speeds from 1 to 4 mps. Figure C-7 (Effect of Wind Speed on Catch of Canadian Nipher Snow Gage) has been adapted from Goodison (12) and shows the relation of the gage height average daily wind speed and the deficiency in catch for the Nipher gage for measurement of snowfall.

Wind measurements are available at some Canadian synoptic stations which are equipped with the Nipher snow gage. For these locations the only calculation required for using Figures C-1 to determine the deficiencies in catch due to wind is to reduce the wind speed from the height of the anemometer to the height of the orifice of the precipitation gages. For other stations with Nipher gages wind movement is not recorded. It will be necessary to estimate daily wind speed values from other nearby synoptic stations that record wind as described in the previous section, Adjustment Procedures - United States.

Daily precipitation records for Canadian Synoptic stations during the period they are equipped with a Nipher snow gage will be adjusted using Figure C-7 for snowfall and one-half of the deficiencies determined using Figure C-1 for rain. In addition to these corrections for wind effects, corrections will also be made for losses from wetting of the Nipher gage and for days a trace of precipitation is reported. An amount of +0.15 mm for each time the liquid is poured from the gage to a graduate for measurement will be used for the correction for the wetting loss. A correction values of +0.07 mm for each day a trace is reported for the Nipher snow gage.

Adjustment for Monthly Precipitation Values for Synoptic Stations

Not all stations have had Nipher gages for the full data base period, 1961-1990. Synoptic stations prior to the use of the Nipher gages were equipped with the MSC standard rain gages for rainfall and the 1 to 10 rule was used for snowfall. Figure C-8 (For Computation of Deficiency in Monthly Catch of Rain, Canadian Standard Rain Gage) was developed from wind and precipitation data for many synoptic stations by computing daily adjustment values and summing for monthly totals. For stations without wind measurement, or for periods without wind measurement, the monthly wind will be estimated from nearby stations following the procedures outlined in the previous section, Adjustment Procedures - United States. .

Figure C-9 (For Computation of Deficiency in Monthly Catch of Snowfall, Canadian Nipher Gage) was developed by Hydex from synoptic station data for the southeastern areas of Canada, similar to the development of Figure C-8. From the two curves of Figure C-8 it is evident that the wind movement adjustment for stations in the Maritime Climate of the eastern provinces of Canada is much less than for locations in the colder and drier climate of Ontario and Quebec.

Climatological Stations Using the 1 to 10 Rule

No technique has been found in the literature for adjusting snowfall measurements using the 1 to 10 rule. Prior to 1960 all AES stations used this method of measurement. Goodison (14) has shown that this method can be subject to substantial error. As for other measurement methods the exposure of the measurement site where the measurement is made is also a factor in how well the method measures the true precipitation. Studies by the NWS at Danville, Vermont, showed that the accumulation of snow on a snow board, or on an area cleaned for measurement of the depth of the snowfall, varied considerably in respect to the true snow fall for different exposure. During the snow measurement studies at Danville, Vermont, NWS researches found that the snow on the ground during a period of snowfall, even in a fairly well-protected site, was observed to move towards the perimeter of a small open area even with very low wind speeds (2 to 3 mph). This complicate the comparison of a snowfall measurement with snow survey data or snowfall measurements and was the primary reason the "black hole" (discussed in the section Exposure of Precipitation gages) was created to provide a truer measurement of the actual snowfall at Danville, Vermont.

No adjustments are planned for precipitation records from the Canadian climatological stations using the 1 to 10 rule. These records will be tested for consistency.

For those synoptic stations having periods of records where the 1 in 10 rule was used prior to the installation of a Nipher gage and the location of the measuring sites have not changed, an indication of required adjustment for the 1 to 10 rule observations of precipitation in the form of snow may be developed. However, because of the effect of different exposure, the adjustment factors may not be universally applied without more data and research.

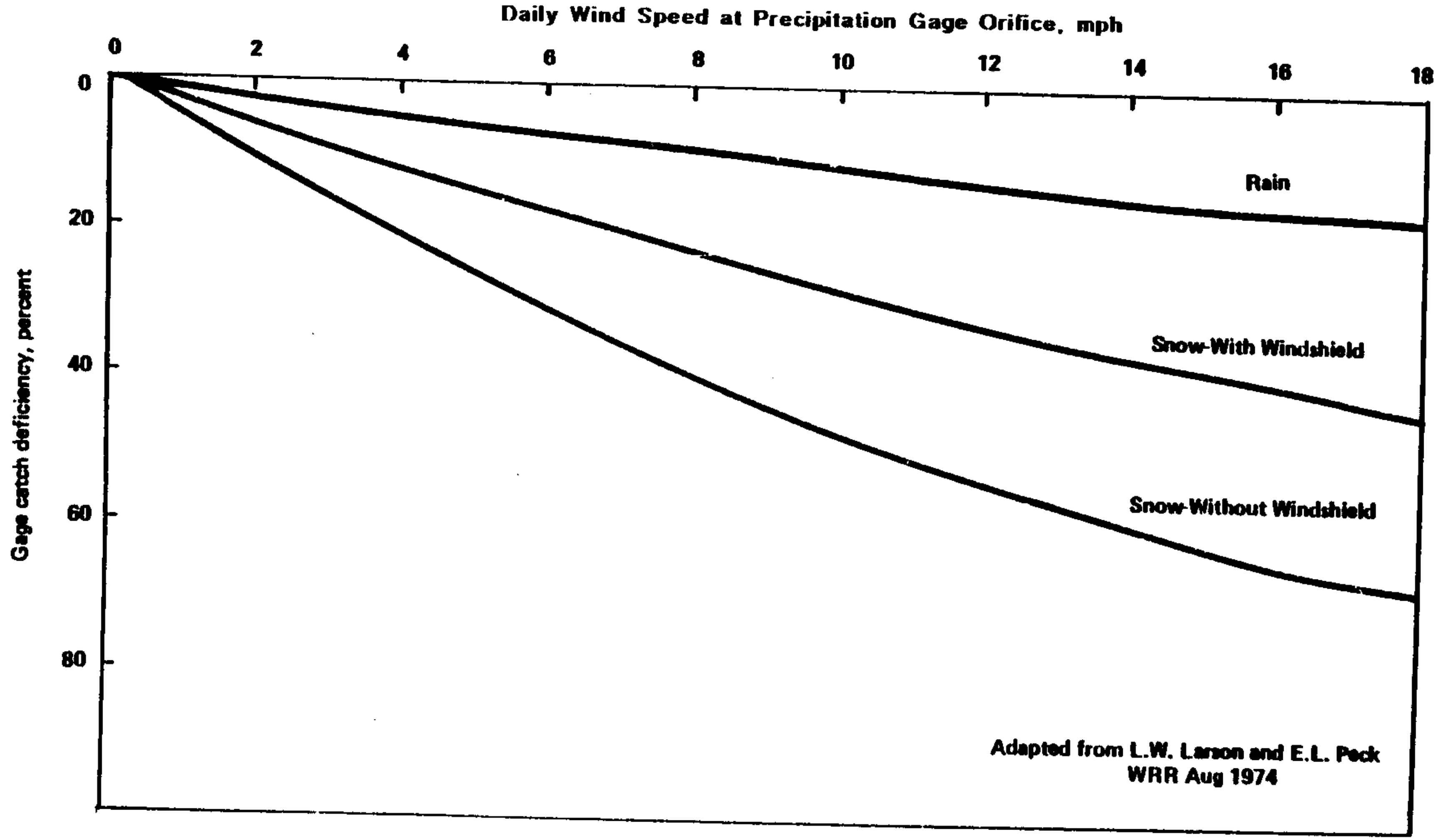


Figure C-1 EFFECT OF WIND SPEED ON CATCH OF U.S. PRECIPITATION GAGES

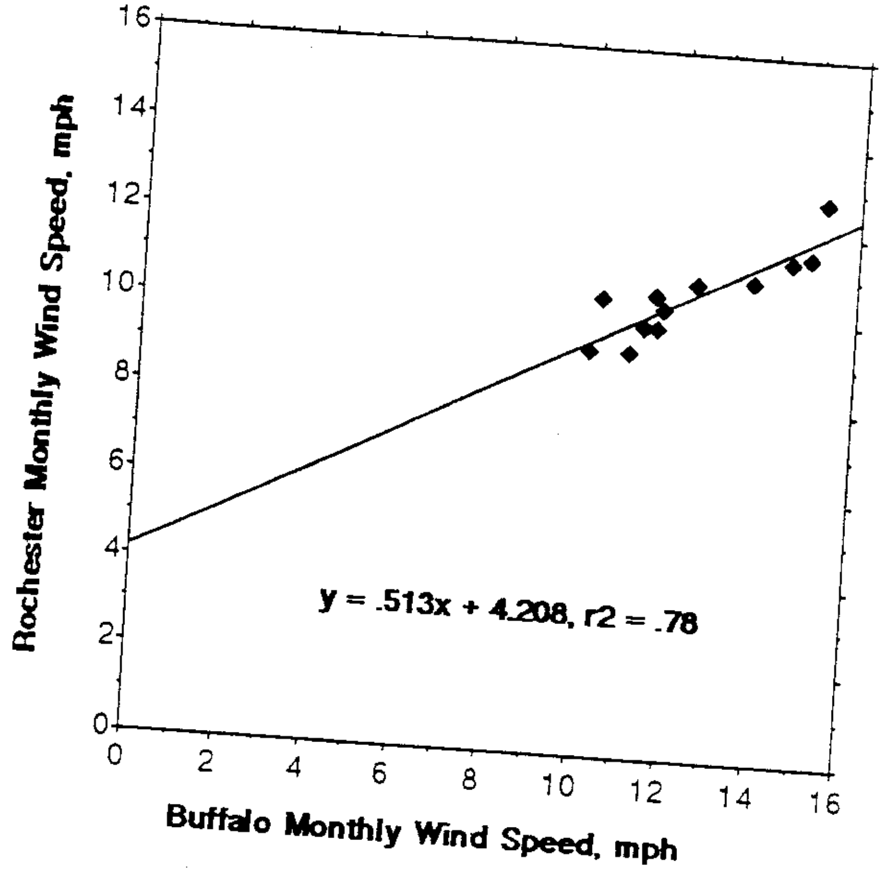


Figure C-2 Average Monthly Wind Speed - Rochester vs Buffalo, 1989-90

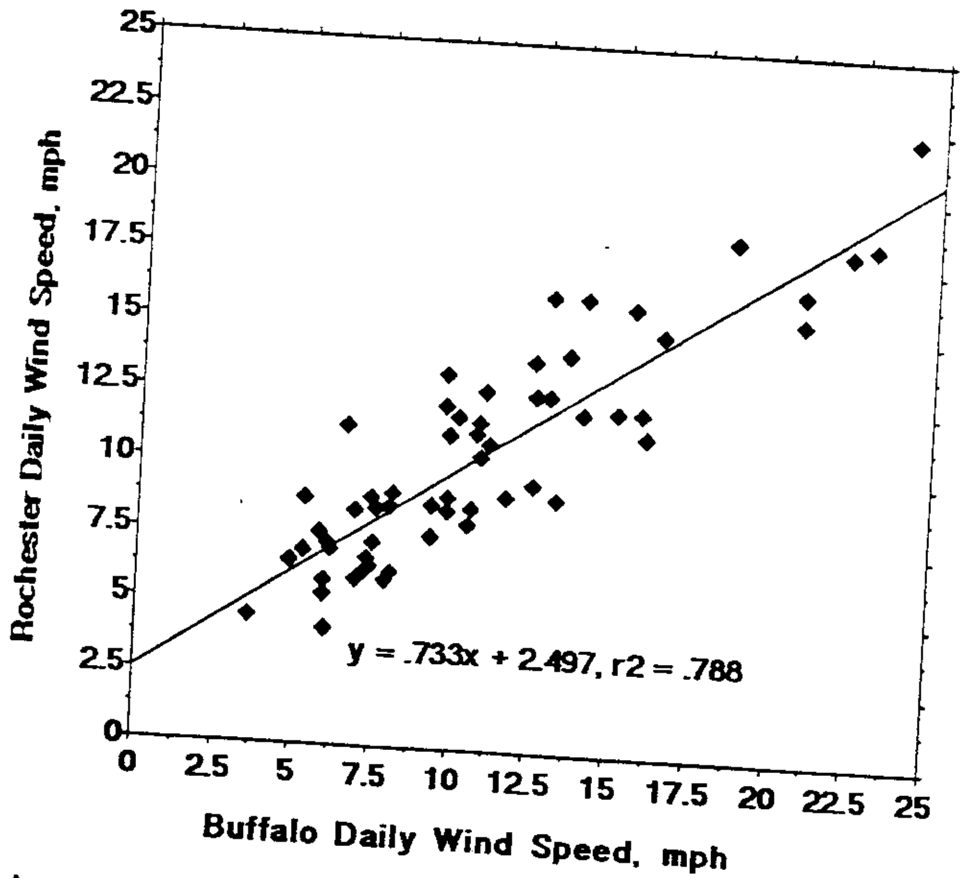


Figure C-3 Average Daily Wind Speed - Rochester vs Buffalo, Feb-Mar 1989.

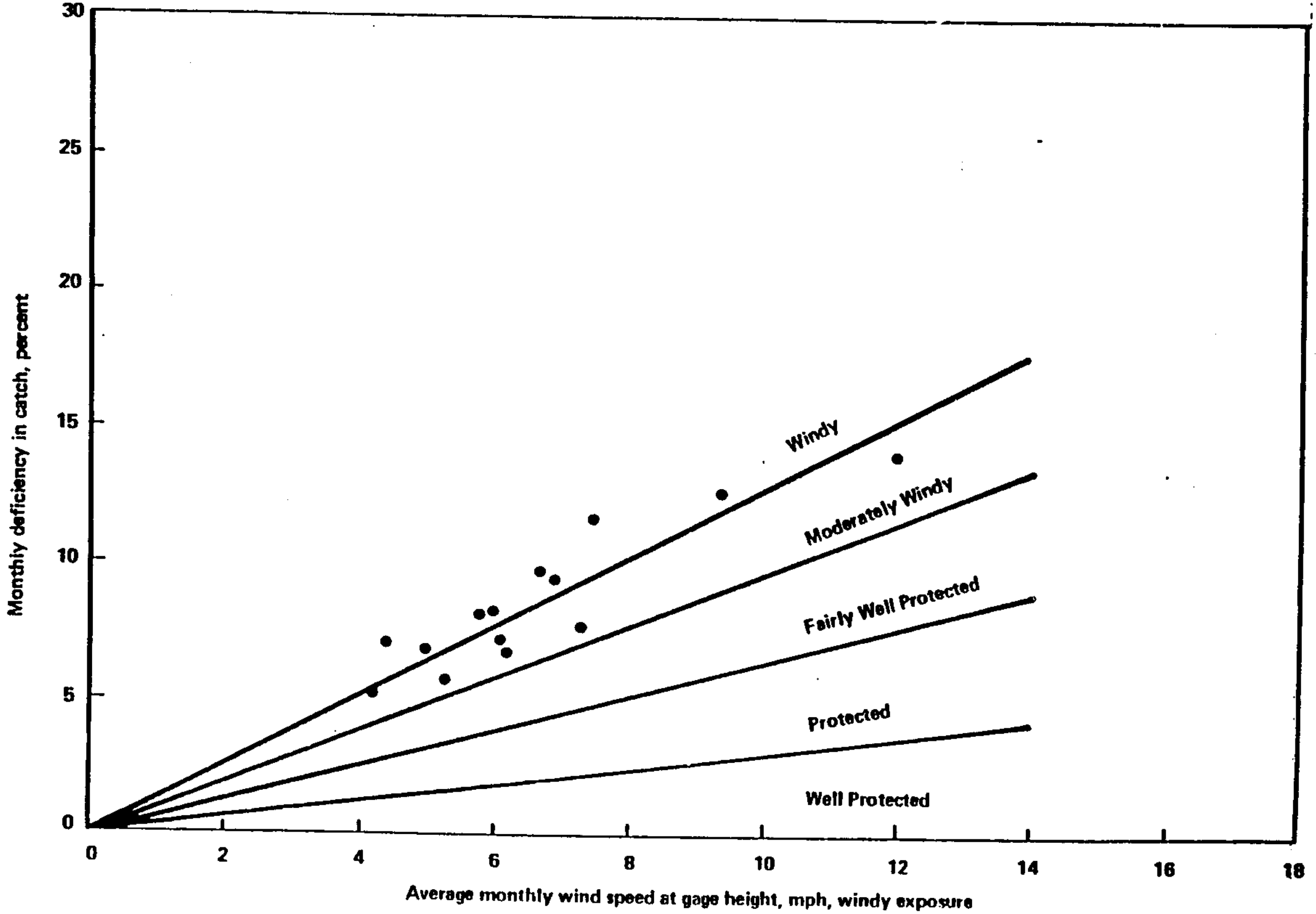
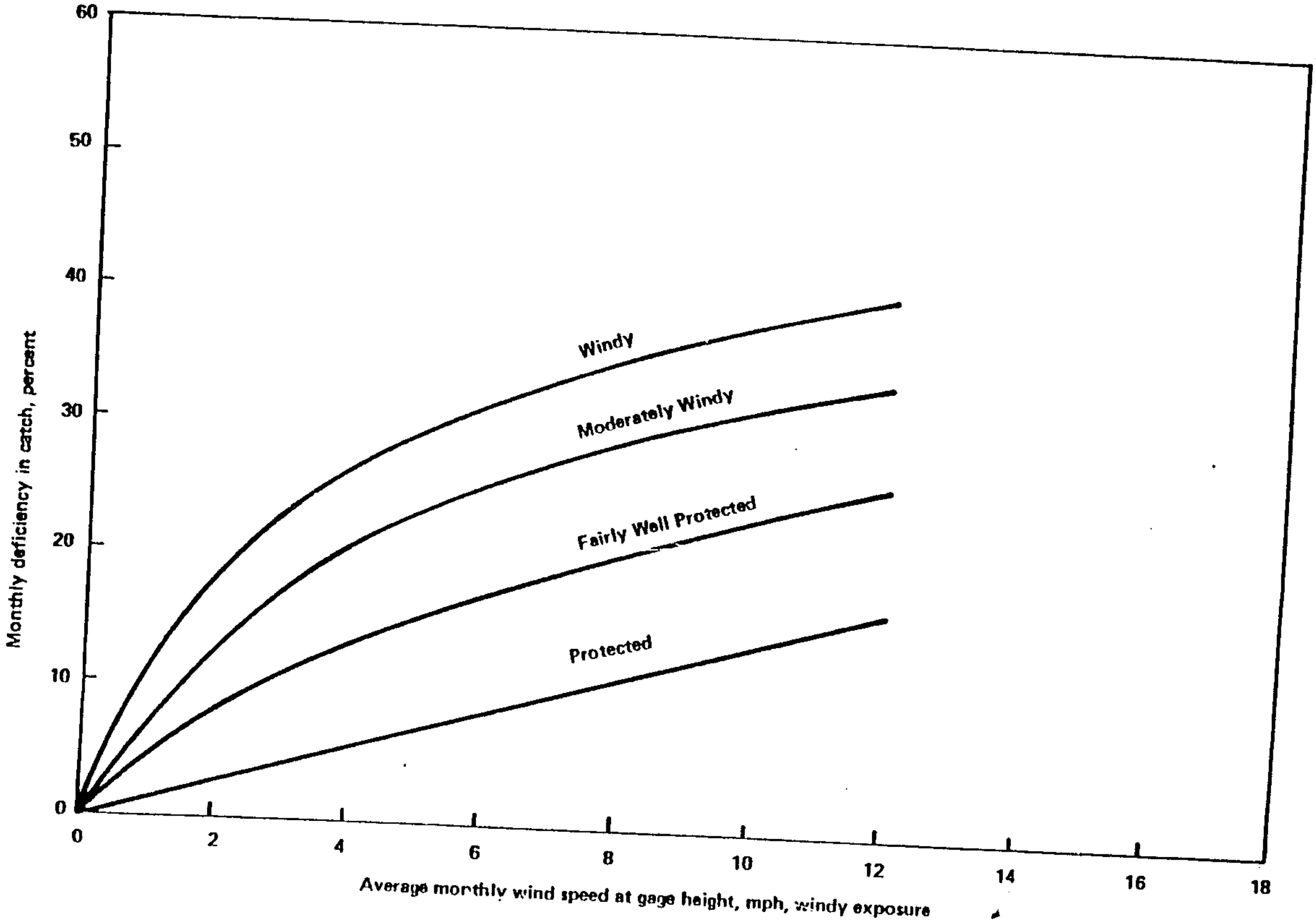


Figure C-4 FOR COMPUTATION OF DEFICIENCY IN CATCH OF RAIN, U.S. PRECIPITATION GAGES


Windy
Moderately Windy
Fairly Well Protected
Protected
Monthly deficiency in catch, percent
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
Average monthly wind speed at gage height, mph, windy exposure

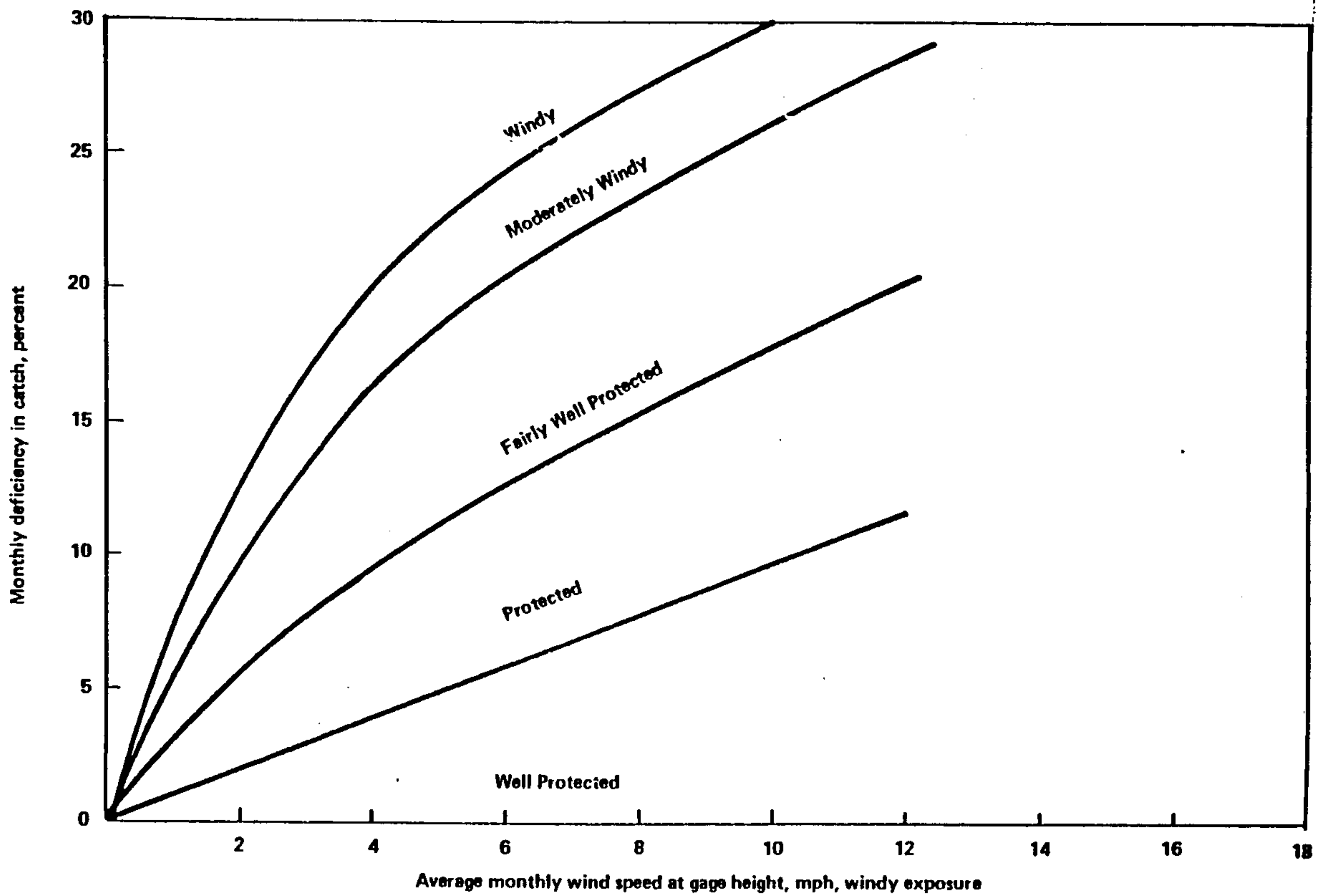


Figure C-6 FOR COMPUTATION OF DEFICIENCY IN CATCH OF SNOWFALL, U.S. PRECIPITATION GAGES WITH WINDSHIELDS

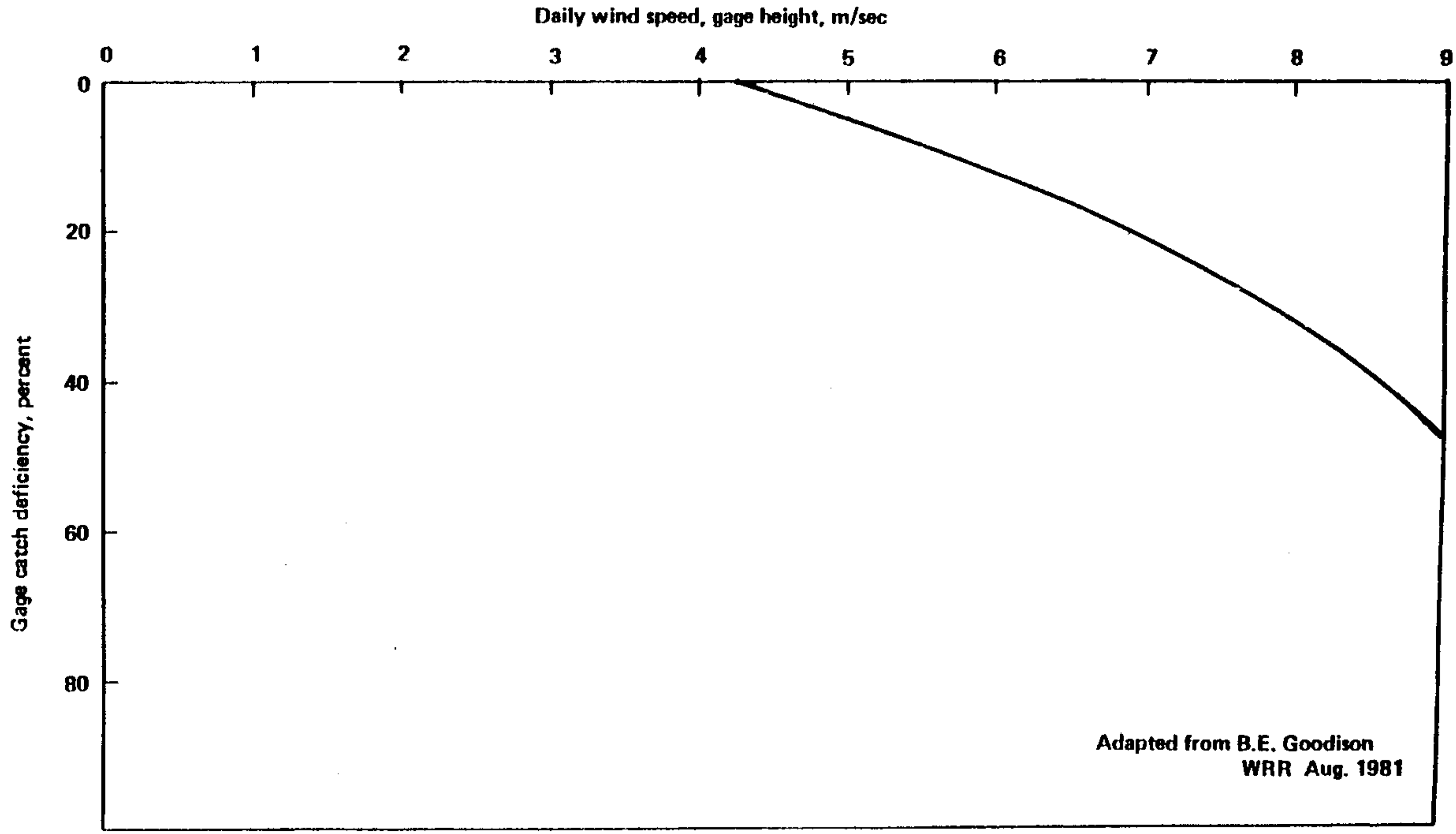


Figure C-7 EFFECT OF WIND SPEED ON CATCH OF CANADIAN NIPHER SNOW GAGE

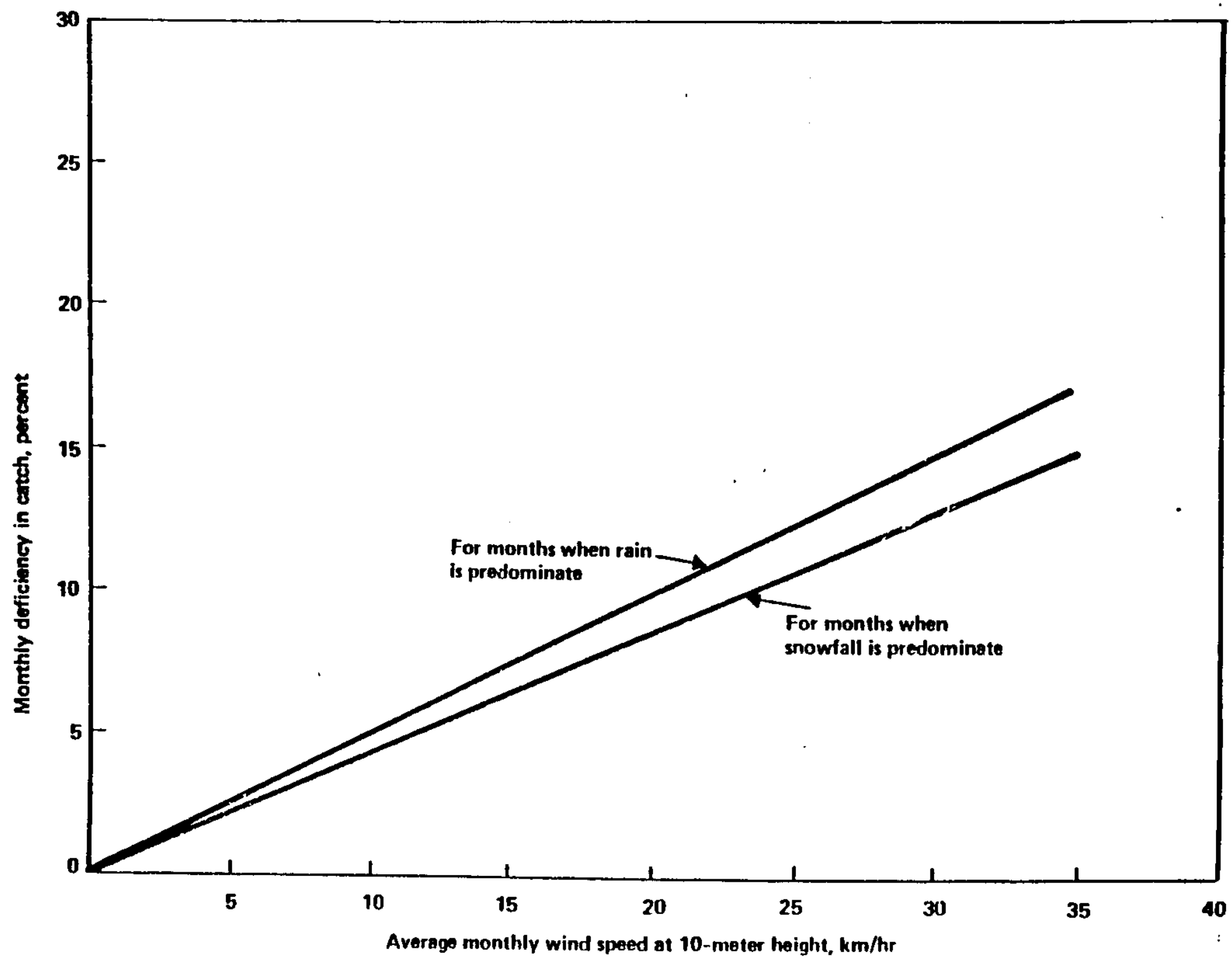


Figure C-8 FOR COMPUTATION OF DEFICIENCY IN MONTHLY CATCH OF RAIN, CANADIAN STANDARD RAIN GAGE.

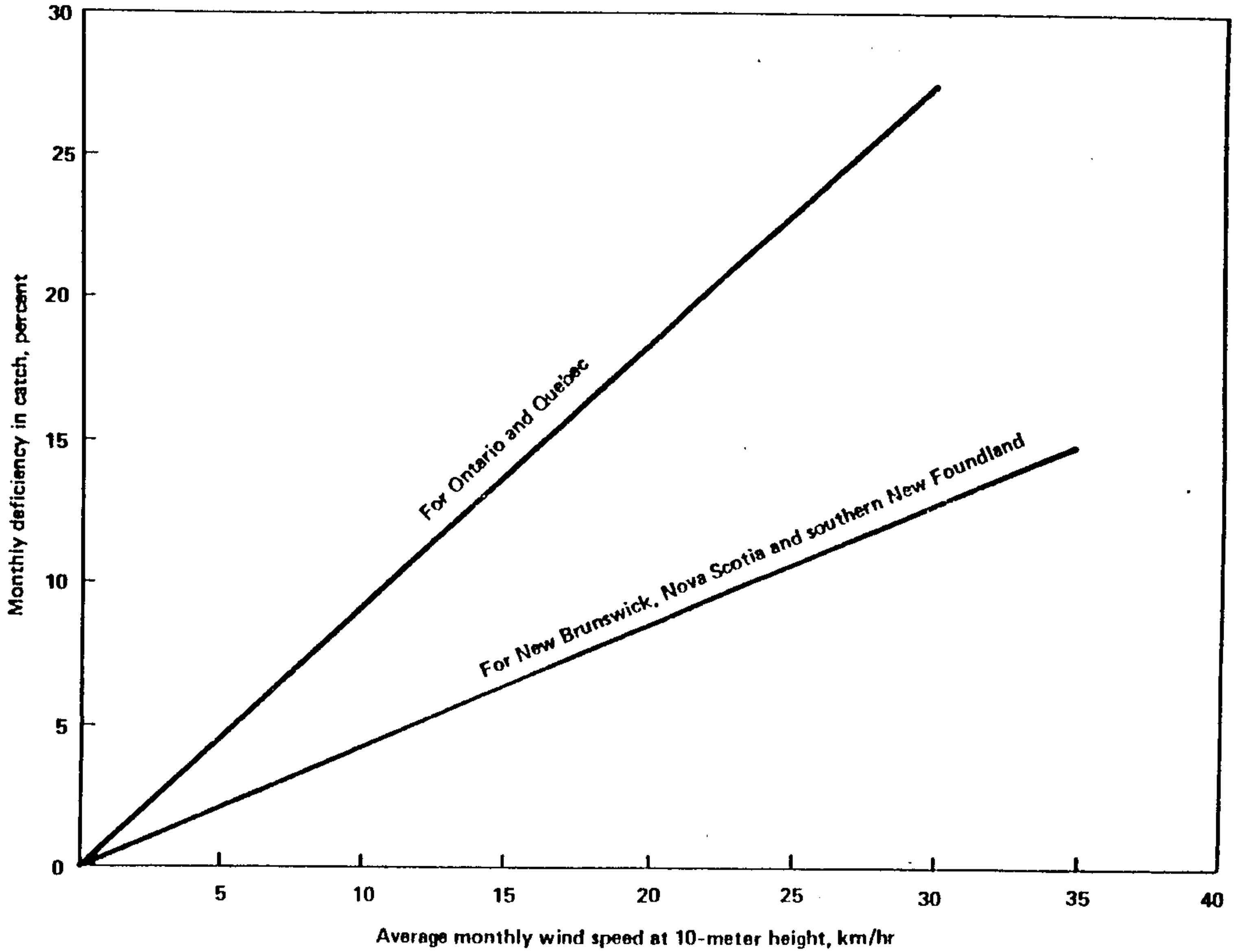


Figure C-9 FOR COMPUTATION OF DEFICIENCY IN MONTHLY CATCH OF SNOWFALL, CANADIAN NIPHER GAGE

Hydrometeorological Data Collection Design and Analysis for the Lake Ontario Drainage Basin

FINAL REPORT - PHASE I
MAY 24, 1991

ATTACHMENT D

CONSISTENCY AND QUALITY EVALUATION OF RECORDS

QUALITY OF GROUND SNOW SURVEY RECORDS

One of the primary objectives of this study is to check all records for consistency and to evaluate the quality of the records. As discussed in the main report, quality evaluation of the ground snow surveys records will be accomplished during Phase II and Phase III because of the limited number of airborne snow surveys now available.

CONSISTENCY OF PRECIPITATION RECORDS

The double mass analysis technique is being used for the first check on consistency of the precipitation and other hydrometeorological records. Many of the US and Canadian precipitation records have been analyzed. A primary reason for inconsistency in a record is a result of moves in the location of the gage or changes in the type of equipment. The inconsistency in the precipitation measurements may be due to differences in exposure of the precipitation gage as discussed in Attachment C,

Experience has shown that several months of the winter period are normally best suited to use as a base in the double mass analysis technique. For this reason, the winter period October - April has been selected for the initial analyses. These plots often shows inconsistencies in the records that correlates with the changes indicated in the station history files. Most of the errors in measurement of snow occurs when the precipitation is in the form of snow. In the US portion of the Lake Ontario drainage area this is primarily during the months of December through February.

Initial October-April double-mass analyses for the US precipitation stations have indicated that a large percentage of stations are inconsistent. Analyses to date show much less inconsistency in the Canadian precipitation records. Separate double-mass plots of December-February precipitation against base values (as well as comparison by the ratio method) are being prepared for stations showing inconsistencies.

An example of a double-mass analysis of October-April precipitation for the Highmarket, New York station is shown in Figure D-1. The adjustment factor found for the period Oct-Apr for 1956 through 1984 was 1.25. Part of the difference in relative catch for the two periods (at different locations) could be for other than under catch. It should also be noted that most of the under catch of snowfall would occur during the months of December through February so adjustment factors for these months would be greater than the 1.25 found for the October-April period.

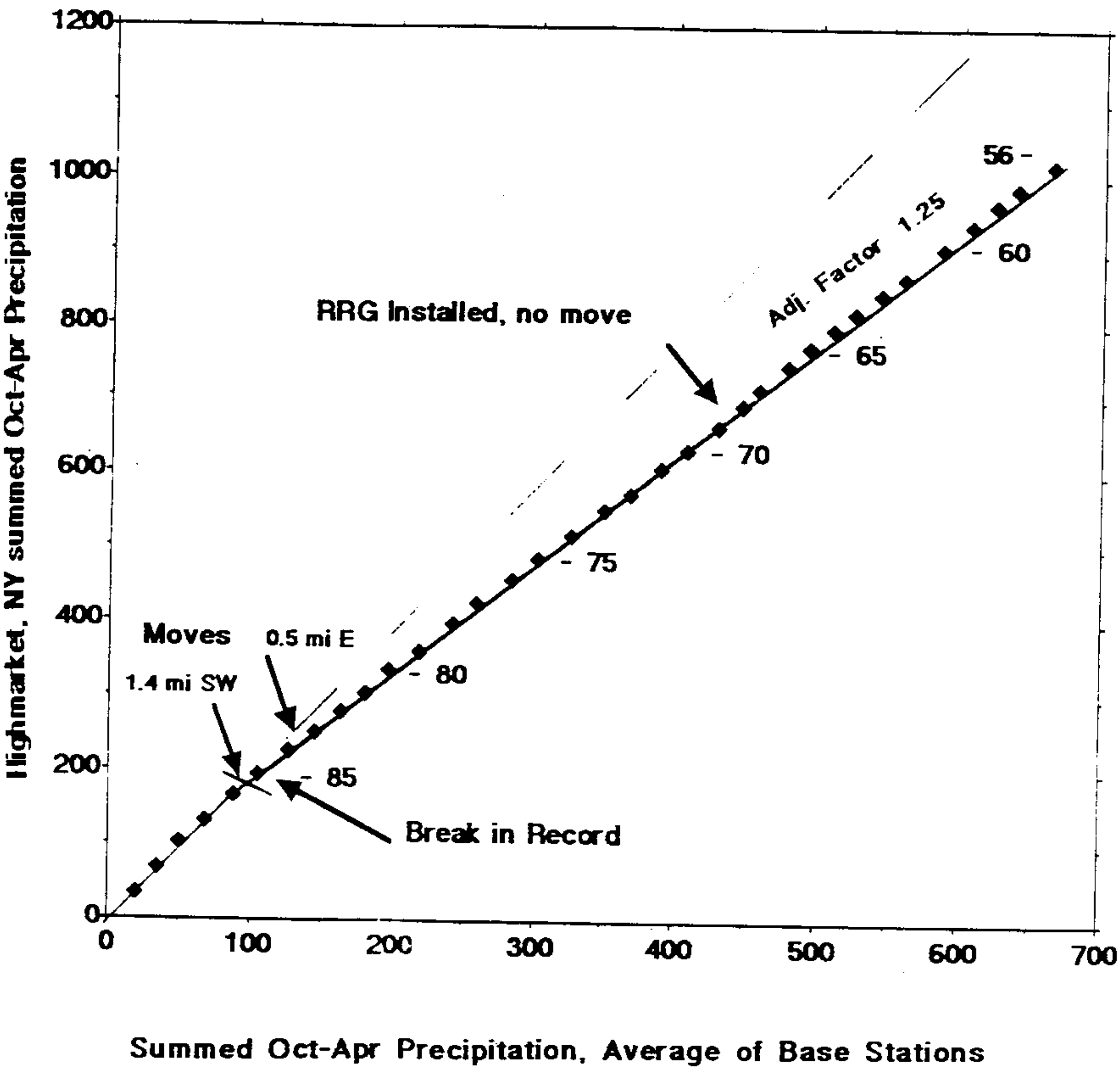


Figure D-1 Double Mass Plot of Highmarket, NY Oct-Apr Precipitation with Average of Base Stations

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